SCIENCE FOR THE ELEMENTARY SCHOOL

SCIENCE

for the

ELEMENTARY SCHOOL

EDWARD VICTOR

Professor of Science Education
Northwestern University

THE MACMILLAN COMPANY / *NEW YORK*
COLLIER-MACMILLAN LIMITED / *LONDON*

Table 11–1, "Relative Humidity Index," has been reproduced by permission of The Macmillan Company from J. Darrell Barnard, Celia Stendler, Benjamin Spock, and Lon Edwards, *Science: A Key to the Future,* © 1962 The Macmillan Company.

First Printing

Library of Congress catalog card number: 65–10303

The Macmillan Company, New York
Collier-Macmillan Canada, Ltd., Toronto, Ontario

PRINTED IN THE UNITED STATES OF AMERICA

To

MY WIFE *Jeannette*

AND

MY DAUGHTER *Amy*

PREFACE

THE PURPOSE *of this book is to help prospective and experienced elementary school teachers organize and conduct meaningful science learning experiences in the classroom. It consists of three major sections: (1) the teaching of science, (2) science content, and (3) learning activities. All three sections are vital, because to teach science successfully the teacher must be equally familiar with the philosophy, content, and techniques of teaching science in the elementary school.*

The book is divided into two parts. Part One is about the teaching of science in the elementary school; in Part One are the usual, but important, chapters on the broad goals of the elementary science program, objectives of elementary science, methods of teaching science, sources of science materials, and evaluation of science learning.

Three additional chapters that should be of tremendous benefit to the teacher have been included. One of these chapters discusses the prerequisites of an effective elementary science program, suggests in great detail how to organize a science program and develop a curriculum guide for a school or school system, and furnishes as a guide a representative scope and sequence chart for grades K–6. The second chapter describes, step by step, how the teacher can construct a structured unit that will enable her to teach science competently in the classroom. The third chapter submits sample science units that can serve as models for the teacher when she is constructing her own units.

Part Two contains science content, learning activities, and bibliography. The science content is presented in an unusual manner, namely, in outline form. Usually the science content is presented in much the same way that it appears in a junior or senior high school textbook. Often this textbook method of presentation is not helpful to the teacher, especially when the teacher's science background is limited. Some teachers have difficulty in distinguishing between key concepts and supplementary material in the wealth of science material before them. Others find that the science content is not presented in a logical sequence that lends itself easily to classroom teaching and learning. Quite often the science content contains terms that are too abstruse for the elementary school teacher.

In an effort to eliminate these problems, the science content in this book is presented in outline form, simply and clearly, yet with detail enough to ensure complete comprehension. This format should help the teacher in many ways, all of which will contribute to better teaching and learning in the classroom.

1. The outline form lends itself to the presentation of concepts in a logical learning sequence.

2. By eliminating all extraneous material, the outline form makes the key concepts in any science area clearly and easily identified.

3. The outline form makes it easier for the teacher to select concepts for use in lesson plans and unit construction on different grade levels.

4. The simple wording in the outline makes it easier for the teacher to bring the vocabulary of the concepts down to a level appropriate for children in the elementary school while preserving the accuracy and flavor of the science content.

5. The outline is sufficiently detailed so that it not only ensures complete comprehension of the science concepts, but also provides the teacher with ample material for daily lesson and unit plans. In fact, more science content has been included than is usually taught in grades K–6. The additional material is intended for the fast learner.

The learning activities that follow the science content in each chapter are not all-inclusive. Their purpose is to familiarize the teacher with one representative learning activity that can be used to teach each of the key concepts in the outline. Additional activities may be found in elementary science textbooks, sourcebooks, and reference books.

I am indebted to a large number of persons who have played a part, either directly or indirectly, in the writing of this book. These persons include the many elementary school teachers with whom I have worked. They have helped me clarify my concept of what constitutes good science teaching and learning, and have made me acutely aware of the problems involved in the teaching and learning of science in the elementary school.

I would like specifically to thank Dr. Paul J. Misner, Superintendent of the Glencoe, Illinois, school system for granting me permission to photograph children and teachers in their classrooms, and Marvin Martin, teacher in Glencoe's South School, for taking all the photographs. Finally, I am indebted to my wife, Jeannette Victor, for typing the entire manuscript.

EDWARD VICTOR

CONTENTS

PART ONE
Teaching Science IN THE *Elementary School*

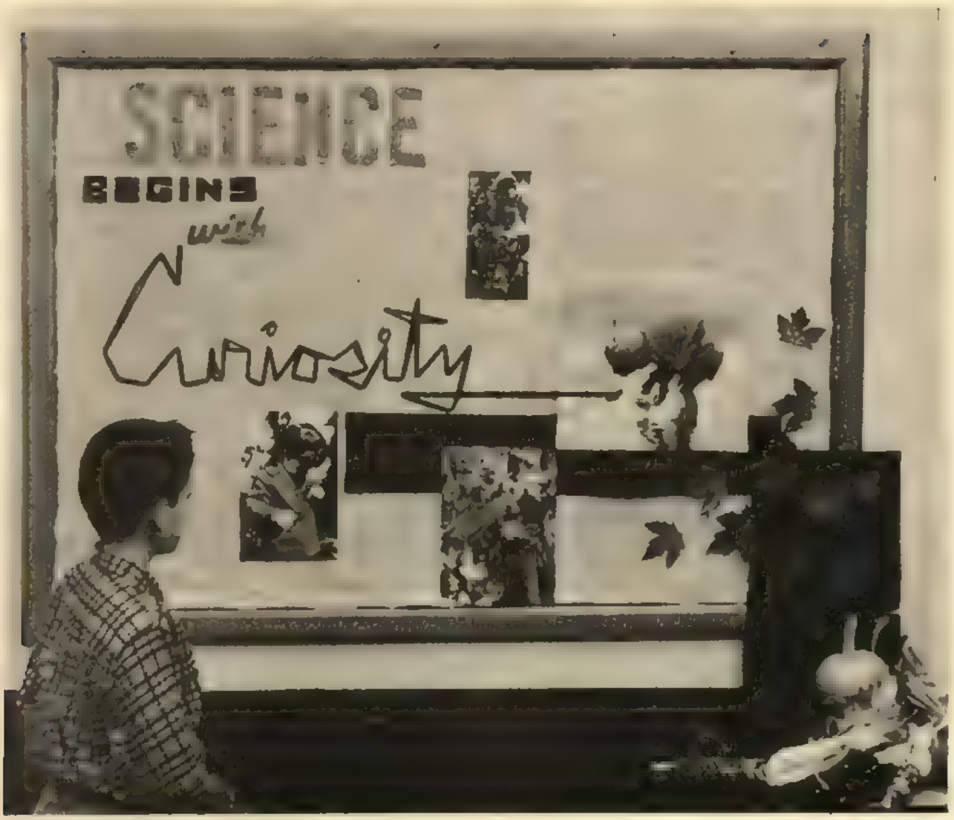
PART TWO
Basic Science Information, Learning Activities, AND *Bibliography* FOR *Science* IN THE *Elementary School*

PART ONE

Teaching Science IN THE *Elementary School*

CHAPTER

1



Science *in the* Elementary School

TODAY there is a strong movement to make science a dynamic and integral part of the elementary school curriculum. School communities have begun to think in terms of an overall K–12 science sequence. This kind of thinking means making specific provisions for a continuous, integrated science program—with definite scope and sequence—from kindergarten through grade 6.

As a result, schools throughout the country are devoting a tremendous amount of time and attention to elementary science. Committee meetings and workshops are being held everywhere, either to reorganize existing elementary science programs or to develop new ones. In each case much more science is incorporated into these programs. Many concepts and

principles that were commonly assigned to the junior high school are now reallocated to the elementary school. Material that was previously taught in the upper elementary grades is now being taught in the lower and middle grades.

There is a trend among state departments of education to increase the science prerequisites for those persons planning to become elementary school teachers. Many teacher-training institutions have already raised the science requirements for their prospective teachers.

Experienced elementary school teachers are receiving in-service training so that they can keep pace with the increased science content in the new programs. This training is offered either in colleges and universities or in the schools themselves. Special courses, also for this purpose, have been sponsored under the National Defense Education Act. At the same time the National Science Foundation has underwritten special institutes for elementary school teachers, designed to strengthen their science background and thus increase their teaching effectiveness in the classroom. The position of elementary science supervisor is becoming more prevalent, both in state departments of education and in individual school systems.

More science materials have become available because of this movement in science. New elementary science textbooks are appearing, and existing series are being revised. A large variety of sourcebooks of experiments and demonstrations have been published, and the number of methods books on the teaching of elementary science has increased. School systems are beginning to make specific provisions for science materials in their elementary school budget. The federal government, in turn, is now providing financial aid to the elementary schools for much needed science books, supplies, and equipment.

Although several reasons can be offered to explain this unusual activity in elementary science, most of the reasons can be grouped under two main factors.

The first factor is the vast and almost explosive scientific and technological revolution in our midst. Science has already produced great changes and upheavals, and we can expect more changes and upheavals in the future. Atomic fission, the A-bomb and the H-bomb, atomic fusion, guided missiles, and man-made satellites have made their impact upon our ways of living and manner of thinking. Space travel, with its implications and ramifications, is next on our horizon.

A comparatively simple civilization has now been replaced by an exceedingly complex and bewildering one. Furthermore, the steadily increasing influence of science and technology upon mankind is beginning to become a source of concern to society. It is imperative that we give our children not only an adequate preparation for the kind of life this scientific and technological revolution will provide, but also a suitable understanding of the relatively few basic scientific concepts and principles—and their relationships—upon which these scientific advances are based.

Consequently, all kinds of people—administrators, teachers, parents, educators, scientists, journalists, as well as civic and national leaders—are

vitally concerned with the kind and amount of science being taught and learned in our schools today. There is a general feeling that the time is ripe for a new movement in science education, and that elementary science must play an important part in this movement.

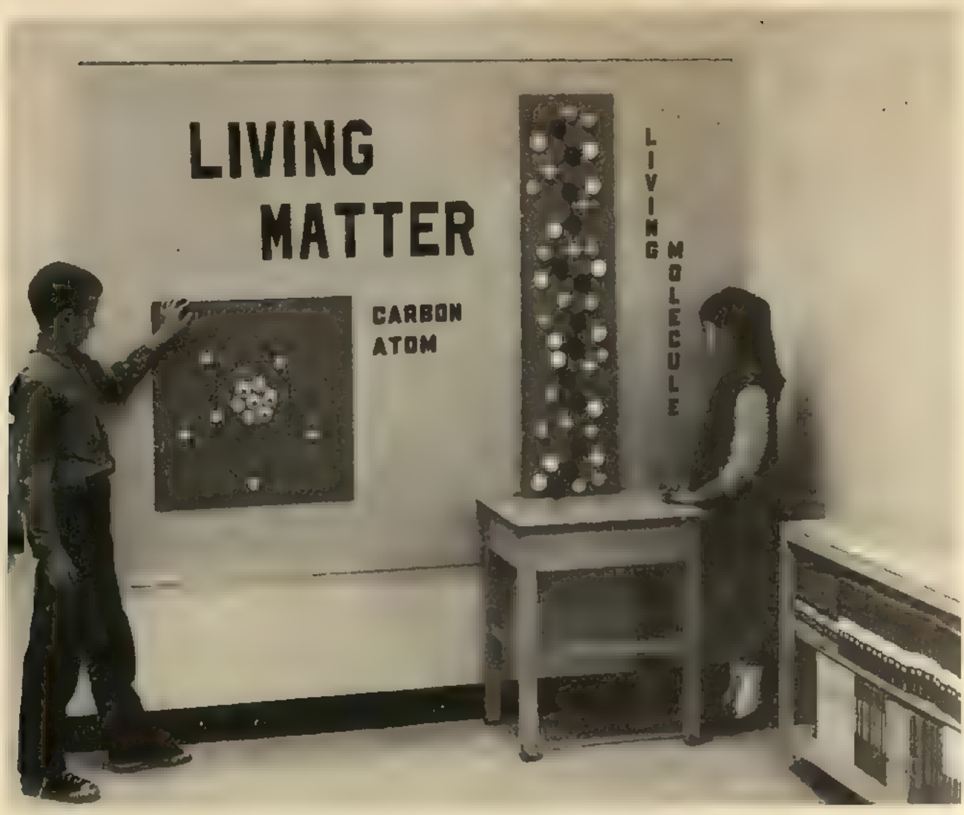
The second factor responsible for the present activity in science education is much less obvious and immediate than the first factor, but it is nevertheless equally powerful. This factor is the slow but steady trend to bring science down from the high school and junior high school into the elementary grades. It may be that the present movement in elementary science would have been accomplished eventually, without the scientific events of the past few years. For more than thirty years science educators have repeatedly recommended a strong science program in the elementary school. The impact of these recommendations was already beginning to become evident in the elementary school when the scientific revolution began. However, the scientific revolution has obviously acted as a powerful catalyst in hastening the trend of science education downward into the elementary school.

History of Science in the Elementary School

SCIENCE was the last of the major subject areas to be included in the elementary school curriculum. Until 1875 practically no science was taught in the elementary school, the emphasis being upon reading, writing, spelling, and arithmetic. Shortly thereafter, *nature study* was introduced in a few scattered schools. Its purpose was to get the children to know and love their environment by observing everyday things around them. The emphasis was on getting the information about our environment from first-hand observations rather than from books. This idea became increasingly popular, and the nature study movement began to grow. By the end of the nineteenth century a large number of elementary schools in several states included nature study in their curriculums.

However, from almost the beginning this movement encountered obstacles and criticisms that increased rather than decreased with time. At its start, nature study was introduced by people who were both specialists in science and master teachers. They were able to make the study of nature a dynamic and unforgettable learning experience for the children. However, once entrusted to teachers with little or no background in science and with varying degrees of teaching effectiveness, the study of nature in the elementary schools deteriorated badly.

Undue emphasis was placed upon incidental items. At the same time identification and classification became increasingly important. A study of birds, for example, was primarily concerned with the recognition of local species only. The children were put to work collecting and studying pictures of these birds. Eventually identification and classification became the end, rather than the means to an end.



Science is more than nature study.

A variety of books on nature study appeared, many of them written by persons who had a meager science background. Learning activities involving firsthand observation gave way to reading about nature in books, where much of the science content was often only partially correct, and where fable, fancy, and fairy tale were usually interspersed with the science. In many of these books songs and poems about nature were given equal space and importance.

When discussing nature study in the elementary school, proponents advocated that the program include the physical sciences. This recommendation, however, never proceeded beyond the theoretical stage. In practice, nature study was concerned primarily with plants and animals. This emphasis may have been the result of the fact that the chief advocates of nature study were usually persons who had specialized in the biological sciences. Only occasionally was some study of the earth, rocks and minerals, and the sky included, depending upon the science background of the teacher.

Although the basic assumption in nature study was that the children's interests would be one of the guiding factors in what would be learned in the classroom, often a highly specialized and rigid program emerged, with a selection of content far removed from the children's interests.

Early in the twentieth century it was obvious that nature study was not

successful. Its popularity waned steadily, and the movement died out, although vestiges appeared in many elementary schools. Even today some schools tend to teach biology in grades 1–3 and physical science in grades 4–6. Yet, despite its faults and drawbacks, the nature study movement did make one important contribution. It directed attention to the child and his need to be aware of and know more about his environment.

Meanwhile there appeared a slow but definite trend to bring science down from the colleges into the schools. The teaching of science appeared in the high school, imitating the college by presenting the subject matter as a body of classified knowledge. Soon after the junior high school was established, general science was introduced, first into the ninth grade, and later into the seventh and eighth grades. In the junior high school, the objectives for teaching science gradually focused more upon the child and his relationship with his environment.

As the teaching of general science in the junior high school increased in popularity, it became apparent to many that much of the science content in the junior high school program was of vital concern to the children in the lower grades. Science educators became convinced that these children could learn much of the junior high school science, provided it was simplified to their level of understanding.

Thus, a new movement arose, advocating a continuous K–12 science sequence in our schools. This movement grew steadily, and schools throughout the country began to give much consideration to their elementary science programs. The advent of Sputnik in 1957, with the subsequent universal interest in science education, gave tremendous impetus to the movement, and since then it has been advancing rapidly.

Today there is unanimous agreement that there should be a strong K–12 science sequence in our schools and that the science program in the elementary school should be highly developed to play its proper part in this sequence. Both scientists and science educators are firmly convinced that our children are capable of learning more science than was hitherto thought possible, and that this is especially true for the elementary school. Consequently, we find ourselves on the threshold of a new era in elementary science.

The Role of Science in the Elementary School

THE RECOMMENDATION of a continuous K–12 science sequence in our schools has been received with almost immediate approval and has met with wide acceptance. An ever-increasing number of elementary schools are either developing new science programs or reorganizing existing ones. It is imperative, then, that all those concerned with such programs understand clearly the role of science in the elementary school. To fulfill this role there should be at least six broad goals for the elementary science program.

HELPING OUR CHILDREN UNDERSTAND AND INTERPRET THEIR ENVIRONMENT

The elementary science program should help our children understand and interpret their environment. Children are tremendously interested in almost everything about them. They wonder what makes a rainbow in the sky. Airplanes, rockets, and jets fascinate them. They associate themselves with astronauts winging into space. They have an inordinate curiosity about living things, plant and animal. They love to tinker with gadgets, mechanical and household. They are delighted with the almost magical effects produced by simple chemistry experiments. They collect seashells and odd-looking stones. They look up into the sky at night and want to know why the moon grows larger or smaller.

Children are interested in the same things about them that interest adults: the sky, the earth, matter and energy, and living things. Furthermore, children can understand and learn many of the basic science concepts upon which the phenomena in our natural world are based. They can use these concepts to interpret their environment. A good science program, therefore, will not be directed toward learning facts, but toward learning concepts and their relationships. Its goal will be understanding these concepts, not rote memorization. The science program should be organized so that there is time and opportunity for the children to reinforce and strengthen their understanding of these concepts. It should help children realize that knowledge about science is cumulative, and that it is usually necessary to use previous knowledge to acquire further knowledge. In the process the children will become familiar with many historical incidents in science, both experimental and biographical, and thus assimilate some of the historical flavor of science. Finally, while learning about their environment, the children will be developing a science vocabulary that will be useful to them in later years.

HELPING OUR CHILDREN LIVE SUCCESSFULLY IN A CHANGING WORLD

The elementary science program should help our children to live successfully in a changing world. We live in a world of change. Scientific and world events happen so quickly that it is virtually impossible to keep abreast of what is going on, as well as to adapt mentally to the resulting changes that take place. Changes are accompanied by a fear of the unknown and anxiety about what the future can bring. A good science program can help allay this fear and anxiety somewhat, and can in some measure prepare our children to live more successfully in this changing world.

The science program can help children understand that nothing is fixed, and that our universe itself is based upon change. It can show that change in science may at first seem frightening because it is inconsistent and unpredictable. However, it can also show that in science there is a pattern and rhythm, and even a definite order, in change. The water cycle, a cycle in

which water continually evaporates and condenses out in many forms, is an example of the rhyme and reason in change. The constant process in which mountains are worn down to become valleys and valleys are built up to become mountains again is another example of the natural order of change in science. Thus, as the children learn more science, they will realize that change is an inevitable part of their lives. Studying and learning about change in science—how and why change happens and the ways and means of coping with change—just as the scientists do, will contribute much to help our children react more intelligently and successfully to the equally rapid sequence of events and changes they may expect to encounter in their future.

HELPING OUR CHILDREN LEARN EFFECTIVE THINKING

The elementary science program should inculcate in our children an effective way of thinking. A good science program will take advantage of the fact that our children have exploring minds and will try to keep their minds exploring constantly. It will encourage the children to look for the cause and effect of things that are happening around them. This seeking of cause-and-effect relationships in turn will encourage real learning to take place, not rote memorization of laws, principles, and understandings. It will also whet, not dull, the children's natural curiosity and enthusiasm. Children who acquire the habit of looking for cause-and-effect relationships have gained something priceless.

The science program can try to get children to think critically and to develop a scientific attitude. It is important to work for the inculcation of the habit of questioning things, making careful and accurate observations, of withholding judgment until sufficient evidence has been collected, and of showing a willingness to be tolerant of and receptive to new ideas. Children can be led to understand that new discoveries are constantly being made that change previous beliefs. What may be accepted today may not be true tomorrow. Therefore it is important for children to keep an open mind in the classroom, as they evaluate their present beliefs, testing, discarding, and retaining beliefs as necessary.

The science program can also develop in the children a positive way of thinking toward science and the scientist. They must be made to understand that the discoveries and advances of science have done far more good than evil. Science has fought constantly to eliminate ignorance, poverty, and pestilence. Often a negative image of the scientist is imprinted in the minds of children. Sometimes an unflattering image is mistakenly created when teachers try to show children how dedicated a scientist can be. What would you expect to run through the mind of a healthy, normal, social youngster when he is told that a scientist is a person who would rather spend all his time working in the laboratory than being with family or friends and a person who is not concerned with money or food or clothing or sleep, but only with the experiments he is conducting? It is likely that most children would consider a scientist an odd character, and this attitude might tend to discourage rather than encourage children from

Science helps children develop successful methods of working.

choosing science as a profession. This impression can be compounded by comic books that often portray scientists as fiendish demons who are constantly plotting either to destroy or conquer the world. Especially today our children should know that science is good, that science has made many contributions to the welfare of society, and that scientists are normal human beings with their fair share of goodwill toward their fellow men.

HELPING OUR CHILDREN DEVELOP SUCCESSFUL WORK METHODS

The elementary science program should develop in our children successful methods of working. Science holds a unique position because of its tendency to promote good working habits. Scientists are constantly confronted with problems and have developed highly effective methods of working while solving such problems. Methods of solving problems may vary among scientists, so that there really is not one accepted *scientific method* of working. Yet the different patterns that scientists use do have many facets in common. The various ways that scientists work and solve problems will be discussed in detail in Chapter 2, "Objectives of Elementary Science."

Children are natural problem raisers and problem solvers. A good science program will give children some insight into the different methods that scientists use to solve their problems. Children can use these methods to solve their problems and, in the process, develop greater insight and the

ability to think more critically and more abstractly. However, the methods of problem solving should never be presented to the children so rigidly that the children are discouraged from trying to do things in their own way. Children can and do learn from their own mistakes, and they sometimes even devise surprisingly interesting and satisfactory solutions.

A science program that attempts to develop effective methods of working makes a valuable contribution to the intellectual growth of children. Each time a child who is confronted with a problem takes a scientific approach when trying to master the problem, the child has proceeded a little toward becoming an intelligent, thoughtful citizen.

HELPING OUR CHILDREN GROW AS INDIVIDUALS

The elementary science program should provide for the individual growth of our children. Children vary widely in abilities, interests, and needs. Gifted children are quick to learn, read easily and rapidly, and remember concepts longer and with sharper detail than average children. They have a longer attention span, greater powers of concentration, and are more persistent in working with problems that confront them. They are intellectually curious, capable of a high degree of originality, and have much initiative. They usually grasp key concepts the first time, and they are able to think more abstractly and critically. They have a strong ability to deduce the basic science concepts that underlie observations and facts, and they can derive further concepts from these deduced concepts. They are extremely critical of their work and are constantly evaluating whatever they do. They have a wide range of interests and are usually versatile in many areas.

On the other hand, slow learners are poor readers, require much time to grasp a concept, and then tend to forget quickly or become hazy about what they have learned. They have a short attention span, cannot concentrate for any length of time, and give up easily when they encounter difficulties in solving problems. They require consistent guidance and encouragement from the teacher; they have little initiative, and would rather carry out than plan directions and instructions. They are slow to grasp abstract ideas and have great difficulty in arriving at key concepts on the basis of observation or reading. They need more concrete, firsthand experiences, with ample opportunity for needed repetition. They are unable to evaluate their work critically and, as a result, have difficulty in correcting their mistakes. They are much more limited in their interests, and often show large differences in capability when participating in various phases of the elementary school curriculum.

The science program can offer a wide range of learning activities for the children, thus making it possible for the school to provide for the varied abilities, interests, and needs that children have. A good science program lends itself well to individual learning, and therefore it is able to help each child develop and grow in science to the utmost of his ability and capacity. This development is especially important for children who display keen interest and competence in science. Challenging experiences

can consistently stimulate their interests and sharpen their competences, thus providing a good basic foundation for future continued study in science.

CORRELATING SCIENCE WITH THE REST OF THE CURRICULUM

The elementary science program should correlate science, wherever possible, with the other phases of the elementary school curriculum. The science program is only one part of the entire elementary school curriculum. However, learning can be more effective when all phases of the curriculum are integrated. The study of light and sound in science, for example, can be correlated very effectively with the study of communications in social science. Plants, animals, and rocks and minerals can be correlated with conservation. There are many opportunities in science to use measurements and other aspects of mathematics.

Arts and crafts are especially suited for correlation with science in the lower grades. One ingenious teacher had her children make an effective mobile when studying weather. The sun and moon were made of cardboard and then painted with appropriate colors. Stars were made or purchased in the stationery store. A jagged arrow, cut from cardboard and painted white, represented lightning. Models of snow flakes were drawn and cut out. For rain the children used strings of pearls and beads. Each pearl, representing a raindrop, was separated by a glass bead that was shaped like a narrow, hollow tube.

Finally, a constant correlation can be made between science and the language arts. Learning to read, write, or talk about science are merely language art activities with special emphasis upon science. The work in science helps to reinforce the work of the language arts program.

Characteristics of the Child

If the science program in the elementary school is to be effective, the teacher must be aware of and utilize what research tells us about the child. Knowing and understanding what psychology says about children will do much to make the teaching and learning of science in the classroom a profitable and rewarding experience for both teacher and children.

The following factors are some of the more important factors the teacher should keep in mind when participating in the science program.

EGOCENTRICITY

Children are egocentric. Everything is important to children insofar as it relates to themselves. This egocentricity is only natural, because children find themselves in a strange yet wonderful world, filled with phenomena that are constantly affecting them. They tend to interpret the phenomena in the light of how the phenomena affect them, and to utilize everything they learn for the express purpose of adjusting more satisfactorily to the

Children are investigators.

world in which they live. The tendency for children to be egocentric when interpreting their environment is heightened by the fact that they live in a world that is dominated by adults who set the rules.

CONSTANT INTERPRETATION OF ENVIRONMENT

Children are constantly interpreting their environment. Children are interested in and affected by all kinds of environmental phenomena. Some children are more interested in or react differently to some phases of their environment than to other phases. However, regardless of the kind of phenomena involved, children continually try to interpret these phenomena. Very often these interpretations are incomplete, or even incorrect, because of the complexity of the science principles involved. However, children will continue to make the effort to arrive at interpretations that satisfy them. In so doing, children show evidence of using their imaginations in developing hypotheses and concepts, and in devising ways and means of verifying these hypotheses and concepts. At the same time the teacher must remember that the children's interpretations will change with maturity. Consequently, children will be engaged in a constant process of revising their interpretations as they grow in ability to understand concepts and to think more abstractly.

CURIOSITY

Children are curious. The children's world is a world filled with wonder and excitement. They naturally are curious about things in every field of

science. Their curiosity will vary, depending upon what catches their interest. They are more interested in things that move than in things that are still. They are more interested in an object that makes things happen than in an object to which things are happening. Their curiosity reaches a peak, however, with things that seem mysterious and magical. A good science program will take advantage of this curiosity to initiate effective learning in the classroom.

LOVE OF EXPLORATION

Children are investigators. Children love to explore. If given an object with which to play, they invariably try to take it apart and then put it together again. They love to touch and feel things. When a boy asks to see another boy's baseball glove, the boy really wants to touch and feel the glove. The same behavior carries into adulthood. Children are always wondering "what will happen if . . ." and suggesting ideas for finding out. The words *what, why,* and *how* are common in their vocabulary. While investigating, children work and learn best when their experiences are firsthand. Therefore the teacher should provide a wide variety of science experiences that involve *doing* learning activities.

ENERGY

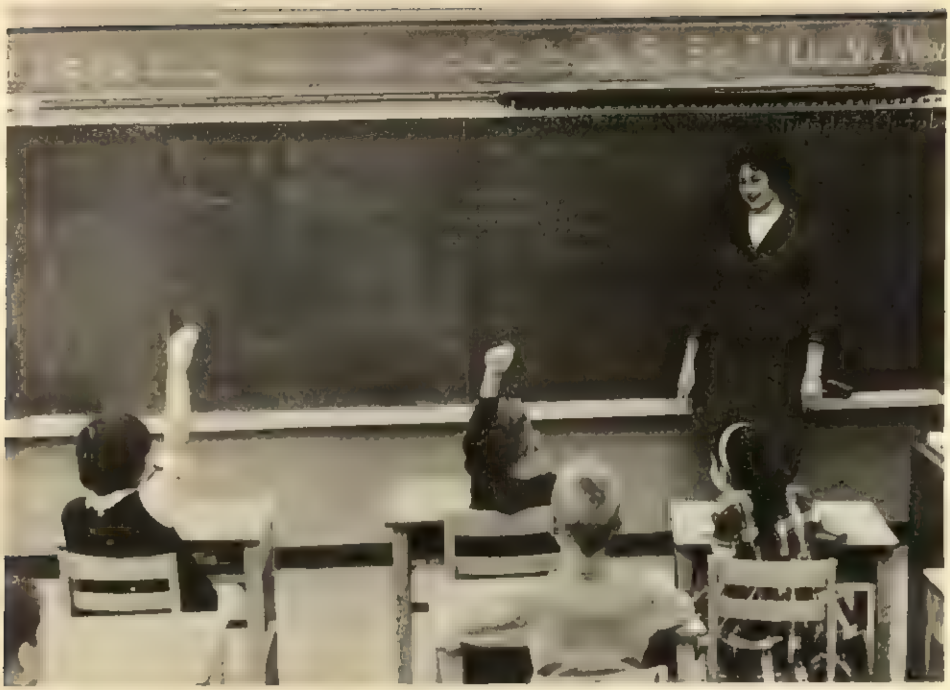
Children are very energetic. They cannot sit still for long periods of time. They would rather do things than listen. Even while listening, they move their bodies restlessly. This restlessness is especially true of boys. The difficulty in sitting still for any length of time has a direct bearing on the children's attention span. As a result, any program that is based primarily upon talking about science will likely have difficulty and probably fail.

PERSISTENCE

Children are persistent. Children like to achieve their objectives. They will often go to unusual lengths of time and effort to solve problems that are important to them. With the solving of the problem comes a feeling of satisfaction and a sense of accomplishment. The teacher can take advantage of the children's persistence and desire to achieve their objectives by introducing the learning of science to them in the form of problems, provided the problems are really problems and not just questions posed in the form of problems.

SOCIABILITY

Children are social persons. Children like to be with and be accepted by their peers. They like to work together in planning and carrying out their activities. If given proper encouragement, direction, and opportunity children will work very well together and engage in all phases of the democratic process. A good science program will recognize this and make provision for the children to participate with the teacher in planning for learning science in the classroom.



CHAPTER

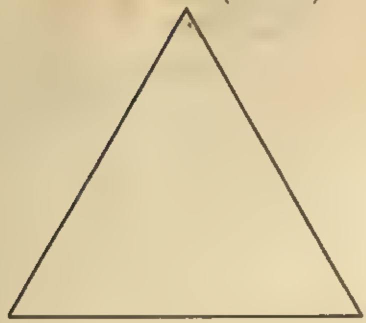
2

Objectives *of* Elementary Science

THERE are three essential components of a science program that must be given serious consideration if the teaching and learning of science in the elementary school is to be effective. These components can be stated quite simply as *why, what,* and *how.* The term *why* refers to the objectives of science that should be achieved. The term *what* refers to the basic science information that should be taught. The term *how* refers to the methods that should be used. In other words, when teaching science in the elementary school, the teacher must know what to teach (basic science information), why it should be taught (objectives), and how to teach it (methods).

These three prerequisites can be thought of as together forming an equilateral triangle, as shown on page 16.

The *why* and *what* form the base of the equilateral triangle, and the *how* forms the vertex. The *how* is the means by which the *what* is learned and



the *why* is achieved. All three are equal in importance and are closely interdependent. One cannot exist or function without the other.

It is imperative that the teacher be completely familiar with the objectives of teaching in the elementary school if real learning is to take place in the classroom. Objectives are vital to the elementary science program. They help justify the selection of science content for the program. They serve as a guide in deciding which learning activities will be used. They become criteria for developing effective methods of evaluation.

The objectives of elementary science are quite specific, yet they are no different from the objectives for the other areas in the curriculum. The only difference is that in this case the objectives are directly concerned with science.

Elementary science objectives are listed in various texts and bulletins. At first glance the lists of objectives may seem to differ slightly, or some lists may appear to be more complete than others. However, on closer scrutiny, all of the lists are found to be in close agreement, and they differ mainly in the way that the objectives are described.

The consensus is that the objectives of elementary science are to help the children learn basic science information and, in the process, to develop desirable behaviors. These behaviors include abilities and skills, scientific attitudes, appreciations, and interests. The behaviors also give the children some insight and experience in how scientists work, especially in critical thinking and problem solving.

Basic Science Information

THE TERM *basic science information* is new. It has been coined in an effort to avoid having to make fine, and often artificial, distinctions between such well-known and often-used words as "facts," "laws," "principles," "understandings," "generalizations," "concepts," and "conceptual schemes." Teachers usually encounter all these terms in their reading, and can readily become confused in trying to distinguish between a fact and an understanding, an understanding and a generalization, a law and a principle, or a concept and a conceptual scheme.

Science helps children understand and interpret their environment.

Although there are definite criteria that may help in making such distinctions, they serve no really useful purpose for the elementary school teacher. The important thing for the teacher to keep in mind is that one of the prime objectives of elementary science is to help the children learn some basic science that will help them understand and interpret their environment. This basic science includes all of the terms described above. Consequently, everything, from facts to conceptual schemes, has been incorporated under one broad and general term, namely, basic science information.

Learning basic science information is an indispensable objective of science in the elementary school. Children who develop an adequate science background have a reservoir of reliable knowledge to draw from and use, and it will affect their thinking, their method of work, the conclusions they draw, and their future behavior.

The teacher must carefully plan the basic science information that will be learned in the classroom. Provision should be made to include the major concepts in science, especially those concepts that have been accepted for a long time and will most likely be accepted for some time to come. New ideas should be added, as they grow in popularity and gain acceptance. These major concepts, then, become the high points around which the teacher's units and daily lessons, and the children's learning, are organized. All work in science is thus directed toward the learning of major concepts and large conceptual schemes.

Learning facts is also important because children must have a command

of the more important facts in science if they are to acquire a firm understanding of concepts. The basic science information to be learned in the elementary school, therefore, should include facts as well as major concepts. But the facts should not be learned as isolated items of information. They should be related so that all together they contribute to the development of key ideas. In this way, that is, by making the basic science information all-inclusive and interrelated, the children will be better able to understand the nature of the universe.

When helping the children learn basic science information, the teacher must have the children *learn,* not memorize.

Consider the teacher who sets up a simple electric circuit, consisting of a dry cell connected by wires to a small porcelain socket containing a flashlight bulb. The teacher announces to the class, while demonstrating the circuit, that this is an electric circuit and that all circuits contain three parts: a source of electricity (the dry cell), a path along which the electricity travels (the wires), and an appliance that uses the electricity (the porcelain socket and flashlight bulb).

How well would you think the teacher has contributed to the children's basic understanding of a simple electric circuit? What assurance would the teacher have that the children had really learned the parts of an electric circuit and their function, and not just memorized them? Would not the very way in which the teacher presented the basic science information be more inclined to warn the children that it would be advantageous for them to memorize the three parts of an electric circuit because most likely this information would be the first question asked in the next test?

How much greater the likelihood that the children would really understand an electric circuit if the teacher used a different approach! In this case the teacher would place before her the dry cells, the wire, and the porcelain socket with the bulb in it, all disconnected. Then she would have the children gather around and she would ask them how they could connect the items together in such a way that the bulb would light up. If the teacher were fortunate enough to have a quantity of these items on hand, this could be a problem that could be solved by separate groups of children. By handling and manipulating the various components of an electric circuit and by finally achieving a successful solution to the problem, there is a greater likelihood that real learning would take place, especially if the experiment were followed by a class discussion.

This approach not only leads to real learning, as opposed to memorization, but also lends itself well to open-ended experimentation. In open-ended experiments the findings of one experiment may produce questions that require another experiment, those findings produce further questions that require still another experiment, and so on. Open-ended experiments involve real scientific investigation. The results are not given in advance by the teacher. The experiment does not necessarily have to arrive at well-known laws and principles. In all cases the experiment should reveal the need for further investigation.

For example, assume that the children have just put together a simple

Learning how scientists work.

electric circuit and have traced the flow of electricity from the dry cell to the bulb and then back again to the dry cell. The circuit is said to be closed, or complete, because there is a completed path for the electricity to travel. Now the teacher—or perhaps some inquisitive child—might raise the question of how switches work in turning lights on and off in the home. This question would lead to a study of switches and also to an understanding of an open circuit. The study of switches might now lead to learning about conductors and nonconductors of electricity, or to the study of fuses, and so on.

This type of experimentation is only one of many ways that can be used to ensure that learning, not memorization, will take place. Such learning is not transitory and quickly forgotten. It proceeds steadily and logically and is stored fairly permanently in the children's minds, to be used again in future learning situations when necessary.

How Scientists Work

Learning how scientists work is a vital objective of elementary science. As an objective it has more than one goal. When children learn how scientists work, they gain insight and practice in the different methods that scientists use to solve problems. They also become familiar with effective ways of working, and they acquire experience in thinking critically. Extremely valuable behaviors can be developed from this learning.

Furthermore, the ways of the scientist can be used to solve problems in other areas of the elementary school curriculum, and even in daily life as well. By keeping this objective in mind at all times and by trying to inculcate it into the minds of the children whenever and wherever possible, the teacher is laying the groundwork for the eventual realization of the children that science is more than just a body of knowledge. Science is also a way of thinking that should govern our behavior at all times.

For a long time it has been the accepted practice in our schools to teach the children that there is a common method used by scientists to solve their problems. The "scientific method," often called the "problem-solving method," is usually described as having five steps that, when followed in regular order, will help solve any problem. The five steps are the following:

1. State the problem clearly.
2. Gather information about the problem.
3. Form a hypothesis or probable explanation.
4. Test to see if the hypothesis is correct.
5. Draw conclusions.

Recently there has been evidence of strong dissatisfaction with this method of presentation about how scientists solve problems. The steps themselves are not criticized. They are valid and desirable operations. The objection seems to be to the way in which this method is presented to the children. Teachers tend to foster the belief that all scientists use only this method and, by following the five steps faithfully, have little or no trouble in solving problems. Moreover, because most textbooks consistently limit the number of steps to five, so many other equally important steps are omitted. As a result, critics maintain that the "scientific method" does not have any real meaning and direction for the children and does not give a complete and accurate picture of how scientists work; consequently, it loses its effectiveness as an objective.

The children should be led to understand that scientists use different methods when solving problems. In addition, although there is a general sequence to the various methods, scientists do not always follow this sequence, nor do they necessarily use all of the steps in the sequence. All the different methods employed by scientists, however, do have several elements in common. It is important that the children become very familiar with all the elements involved.

First, all scientists try to define the problem clearly. This first step is not as easy as it may sound. Sometimes definition is the most difficult part of the entire problem. Scientists often have to analyze and redefine the problem again and again until it is perfectly clear. Otherwise the chances of solving the problem become quite unlikely.

Children will encounter the same difficulty with their problems in the classroom. They will need specific help in recognizing and stating the problem, and here the teacher can help. The teacher should also try to keep the problem simple and within the realm of comprehension of the

children, not only so that it can be defined or stated quite clearly, but also to ensure every likelihood that the problem will be solved. It is almost unnecessary to say that the problem should be real, not just a fact posed by the teacher in the form of a question.

After the problem is stated clearly, the next step is to study the situation carefully for all facts and ideas bearing upon the problem. Careful and accurate observations must be made at this point. Sometimes trying different methods of classifying the data will help greatly in eventually solving the problem. Major scientific discoveries have often resulted because of classifying already known observations in a different manner. It is also important that as much information as possible be collected about the problem.

Now the children will be ready to form a hypothesis—a tentative solution—for the problem. When solving a problem in the classroom or laboratory, usually several hypotheses will be made. The hypotheses may vary from wild hunches to educated guesses based upon previous knowledge or experience. One of the children's tasks, then, will be to narrow the number of hypotheses that have been suggested. Discussion and reasoning can be used to arrive at the most likely hypothesis.

At this point the experimental phase of problem solving begins. Experiments must be found or devised to test the hypothesis. In conducting experiments no one accepted pattern can be followed. Sometimes a single experiment will be sufficient to test the hypothesis satisfactorily. Other times a number of experiments will have to be conducted to make sure the hypothesis is correct. In some cases a control may be necessary or even vital. Some experiments may require quantitative results or extreme precision whereas others may be qualitative and more general. It is important to keep in mind that the kind of experimentation must be such that it will help make it possible for the children to accept or reject the proposed hypothesis.

As a result of experimentation the children will be able to draw conclusions. If the hypothesis is correct, the children will not only have solved the problem, but will also have gained science information that may be of further value to them later. The children may use this information to explain other phenomena or to solve new problems that arise. This procedure is the way children can acquire or build up a background of broad concepts.

Thus, scientists use many methods to solve problems. Although science in the elementary school is on a much simpler plane, children are capable of using the same methods to solve their problems in the classroom. Of course, the children's problems will be much easier than those of scientists, and their methods of solving problems will be less complicated or rigid. The children may at times use only some of the methods. In the primary grades only rudiments of problem solving may be introduced. In all cases, however, the children should be given proper encouragement and guidance in using these scientific methods so that with practice they can become quite proficient in working with and solving problems.

Drawing conclusions.

Another reason why problem solving assumes such importance is that it can give children an opportunity to think critically. In the past, teachers have been too prone to do much of the thinking for the children, especially in science. Yet science is an area that lends itself well to the development of critical thinking, particularly in problem solving. Here the children can think critically when making discriminating observations, when organizing and analyzing facts and concepts, when suggesting and formulating hypotheses, when devising experiments, when giving reasons for expecting particular outcomes, when evaluating and interpreting the results of experiments, and when drawing justifiable conclusions.

The teacher can also tell if children are beginning to learn to think critically when they can apply what they have learned to interpret a new situation. For example, when studying methods of heat travel the children have learned that all matter is made up of tiny particles called molecules, which are in constant motion. This motion of the molecules is called heat. When a substance is heated, the molecules move faster; when a substance is cooled, the molecules move more slowly. In conduction, as one method of heat travel, when one part of a substance is heated, the molecules at the source of the heat begin to vibrate or move faster and collide with the molecules next to them. These molecules, too, now begin to vibrate more quickly, and collide with other molecules next to them. This action continues until all the molecules in the substance are vibrating more quickly, and consequently the substance has become hotter. The movement of the molecules has enabled heat to be passed, or conducted, from one end of the

substance to the other. Now, if the children have really understood and learned this basic science information, they should be able to think critically and apply what they have learned by answering the following question asked by the teacher: "Why does the part of the spoon that is not submerged in a cup of hot water (or cocoa) become hot?"

Again, if the children are learning to think critically, they should be able to predict what will happen when the conditions of a phenomenon in nature are changed. For example, when studying the relationship between the sun and the earth, the children have learned the cause of day and night and of the seasons. If the teacher now asks the children to predict what would happen to the earth if the earth's axis were not tilted at an angle of 23½ degrees, the children will have been thinking critically if they predict that the length of day and night would always be the same, and that different parts of the earth would always have the same season (barring any minor variations caused by the effect of local conditions, of course). It is evident, then, that critical thinking can be an important adjunct for the children when they learn how scientists work.

Desirable Behaviors

It has just been shown that some extremely important desirable behaviors can be developed when children learn how scientists work. Other equally valuable behaviors can emerge from the learning activities in the elementary science program. These behaviors may be either immediate or long-range behaviors. They include abilities and skills, scientific attitudes, appreciations and interests.

Most teachers will agree that these behaviors constitute an important and necessary objective of elementary science. Accordingly, these behaviors are invariably included as objectives for lesson plans, units, and courses of study. Unfortunately, curriculum committees and teachers often tend to express all objectives in such broad—and flowery—terms that it is almost impossible to teach for these objectives in the daily work. This is especially true for behaviors, so it is imperative that all objectives involving desirable behaviors be stated clearly and defined specifically so that they may be easily observed or evaluated when learning is going on in the classroom.

A simple illustration will help make this point clear. No one can deny that good citizenship is an extremely desirable objective for the elementary school and should be fostered whenever possible. Citizenship is an extremely general term, however, so when the teacher is urged to teach for good citizenship in the science program (as part of the overall elementary school program), the teacher is often unsure how to achieve this objective. As a result, the teacher usually merely pays lip service to this objective and then forgets about it in the classroom. It should be fairly obvious that citizenship by itself means nothing as an objective and is unteachable unless it is broken down into specifically defined and observable behaviors, which all together constitute a general conception of the term. For example,

Developing abilities and skills.

one of the behaviors that is conducive to developing good citizenship is the ability to work well with others. When this behavior is listed as an objective, the teacher now has no difficulty in observing or evaluating this behavior when an appropriate learning activity is being conducted. When other equally explicit behaviors involving citizenship are included as objectives, they all will contribute to the ultimate development of habits of good citizenship in our children.

Thus, although desirable behaviors may often seem to be intangible objectives, when stated correctly they become just as tangible as other kinds of objectives. Besides, once the teacher is familiar with these behaviors and really begins to look for them, they are quite easy to observe and evaluate. After all, if children have learned not to jump to conclusions on the basis of only one observation or experiment, they will demonstrate this behavior decidedly, just as other children will just as obviously show that they have not yet acquired this behavior.

The teacher, then, should become thoroughly familiar with the desirable behaviors that can be developed in elementary science. When learning activities are being conducted in the classroom the teacher should constantly look for ways and means of inculcating these behaviors in the children.

ABILITIES AND SKILLS

Abilities and skills are listed together here, especially since many abilities can either be classified as skills or broken down into more specific skills.

There are two kinds of abilities and skills: functional and mental. Functional abilities and skills are primarily concerned with instrumental operations and techniques, such as observing, recording, measuring, pouring, and weighing. Mental abilities and skills are associated with problem solving and critical thinking. These behaviors, when properly developed, should carry over into other areas of the elementary curriculum and into daily life.

Examples of behaviors of the kind that can evolve from an elementary science program include the ability to:

1. Make careful and complete plans for solving problems.
2. Develop theories, and to make and test predictions on the basis of these theories.
3. Find or devise experiments that will solve problems or answer questions.
4. Predict the outcome of an experiment, and offer reasons to justify the prediction.
5. Perform experiments involving simple cause-and-effect relationships, and to describe or explain satisfactorily what happened.
6. Plan and execute experiments carefully.
7. Make accurate measurements and readings.
8. Manipulate science equipment satisfactorily.
9. Observe accurately and with discrimination.
10. Observe and describe similarities and differences in experimental behavior, and in objects and their characteristics.
11. Distinguish between pertinent and irrelevant observations and information.
12. Make valid and reliable comparisons.
13. Make quantitative as well as qualitative observations.
14. Organize and classify observations.
15. Explain phenomena on the basis of truth and logic, rather than on the basis of superstition and wishful thinking.
16. Distinguish fact from fantasy.
17. Apply previously learned concepts to interpret new phenomena.
18. Predict what will happen when conditions are changed.
19. Where experimentation is impossible or unfeasible, to determine other appropriate methods of investigation.
20. Distinguish between science books that are read for fun and those that are read for reliable information.
21. Use the table of contents, index, and glossary of science texts and references.
22. Read science content with understanding.
23. Abstract major concepts and understandings from the science content in texts and references.
24. Read and interpret simple charts, tables, and graphs.
25. Organize observations or reading into effective oral or written reports.

26. Develop the verbal and written skills of communication used by scientists.
27. Participate actively in group discussion.
28. Stay close to the topic being discussed.
29. Formulate clear and intelligent questions.
30. Report clearly, concisely, and accurately.
31. Listen intelligently.
32. Work together, in small or large groups.
33. Cooperate with others when planning an investigation.
34. Persevere in projects that are undertaken.

SCIENTIFIC ATTITUDES

Scientific attitudes evolve most often when children are learning how scientists work and also when they are participating actively in learning activities. They have to do with behavior patterns and with mind sets. Some scientific attitudes are intellectual by nature and are developed as a result of knowledge or understanding. Other attitudes are emotional and are based on appreciations.

The following are examples of both kinds of scientific attitudes:

1. Open-mindedness.
2. Willingness to change one's mind in the light of new evidence.
3. Willingness to allow others to question and challenge one's ideas.
4. Suspended judgment, which is the reservation of decisions until all the available evidence has been collected.
5. Reluctance to generalize on the basis of one experiment or limited evidence.
6. Respect for the ideas, opinions, and ways of life of others.
7. Awareness that there is a difference between facts and opinions.
8. Unwillingness to accept statements as facts unless they are backed by sufficient proof.
9. Reluctance to allow decisions to be affected by personal likes or dislikes, anger, fear, and ignorance.
10. Unwillingness to compromise with the truth.
11. Development of the habit of explaining things in a scientific manner.
12. Desirability of checking thinking by doing experiments or consulting reliable books and people.
13. Going to reliable sources for evidence.
14. Awareness that sometimes printed matter is not accurate or correct.
15. Willingness to cooperate.
16. Curiosity about the world in which we live.
17. Unwillingness to believe in superstitions.
18. Awareness that truth itself never changes, but that our concept of what is true continues to change as our knowledge increases.

APPRECIATIONS

Appreciations are often defined as satisfying emotional responses. They must have as a base some background in science. For example, children must first know what science can do before they can appreciate the part that science can play in our daily life. Because appreciations are positive emotions, the teacher must be aware of the strong emotional elements involved. During class discussion the teacher is in an excellent position to point out or help evolve appropriate appreciations at the opportune time.

Appreciations in science are not as numerous as abilities and skills, or scientific attitudes. The following are examples of worthwhile appreciations:

1. The role science plays in our daily lives.
2. The many ways that science can be used to explain the environment around us.
3. The impact of science and technology on our civilization.
4. The influences of science upon man's way of thinking, his relations with others, his religion, and his social responsibility.
5. The role that problem solving and critical thinking can play in our personal habits, attitudes, and relationships.
6. The concept that science is the result of human endeavor and flourishes best when there is intellectual freedom.
7. The constant striving of scientists to know more about the world.
8. The contributions of scientists to the world we live in.
9. The tools and techniques of science.
10. The orderliness of nature and of natural laws.
11. The ever-changing nature of science.
12. The beauty in nature.

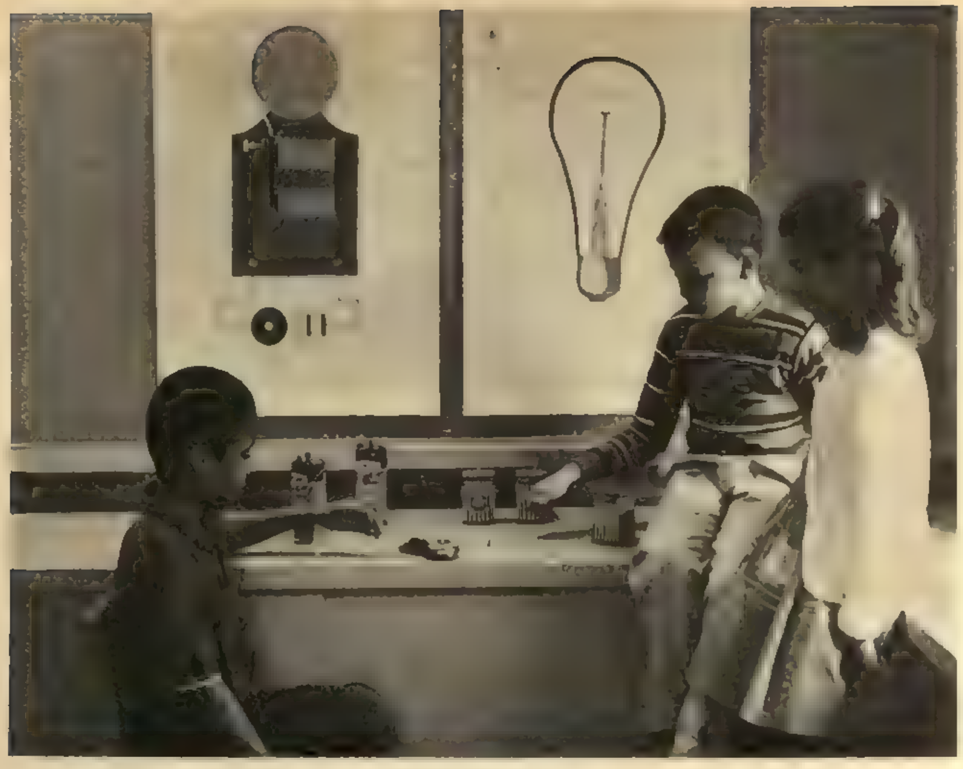
INTERESTS

Interests may or may not have as a base some background in science. Children may develop an interest in photography without a science background, or they may develop an interest in rocks or butterflies because of some science background. Interests are also based on positive emotions, which the teacher can try to evoke at the suitable occasion.

There are two main kinds of interests that can be developed. One kind of interest has to do with science as a vocation. An interest in science in the elementary school has often been a contributing factor in a young person's eventual decision to choose a vocation in the pure or applied sciences. The other kind of interest has to do with avocations. Science is a field that is rife with opportunities to interest young people in hobbies that many will pursue even in later life. Such hobbies include active interest and participation in astronomy, photography, and horticulture. Many persons become interested in tropical and other kinds of fish. Others collect rocks and minerals, seashells, and butterflies or other insects. These hobbies are often started while the children are learning science in the elementary school.

CHAPTER

3



The Elementary Science Program

WHEN A school system undertakes the development of an elementary science program, either as a separate program or as part of a K–12 science sequence, the persons involved in planning begin with an unfortunate handicap. Although a sizable number of excellent science programs for the elementary school are emerging, the details of very few of these programs—if any—are readily available to other school systems for use as guides or examples. As a result, a school system that is involved or interested in developing a new science program is unable to take advantage of the thinking and efforts of those school systems that have already had this experience. Similarly, although prerequisites for an effective elementary science program can be found in many publications, accompanying suggestions for fulfilling the prerequisites are generally not included.

Consequently, the persons entrusted with the organization and development of the elementary science program are confronted with a wide variety of serious, thought-provoking questions. What science content should be included in the program? What guidelines are there for selecting the science content? What are the prerequisites of an effective program? What is the best way to organize and develop the program? How can a scope and sequence chart be developed that is a satisfactory part of a K–12 sequence and is acceptable to teachers, supervisors, science specialists, and administrators? Once the scope and sequence chart is created, what is a suitable procedure for developing a curriculum guide? All of these questions which are discussed in this chapter, must be carefully thought through and answered if the elementary science program is to be a successful one.

The Science Content

SCIENCE content is the second of the three major components of a science program that are considered essential for the effective teaching and learning of science in the elementary school. Science content is the *what* of teaching science. It refers to the basic science information that the children will learn in the classroom.

The problem of selecting the science content for an elementary science program is always difficult. Science encompasses such a wide body of knowledge that it would be impossible for anyone to learn it all, even in a lifetime. It seems obvious, then, that the task is to decide, not how much, but what science should be taught in the elementary school.

Scientists and science educators agree that it is important to select basic science information involving key concepts and conceptual schemes which the children can and should understand. There are many different ways that these major understandings can be learned, even when diversified science content is used. It is entirely possible for children in one section of the country to learn the same concepts and conceptual schemes as children in another section of the country, even though the science content they study will vary somewhat. In the process they all will acquire the same desirable behaviors and thus achieve the objectives of science education.

All science content can be classified into three general areas: the earth and the rest of the universe, living things, and matter and energy. These three areas encompass the five major fields of science: astronomy, biology, chemistry, geology, and physics. There is general agreement that the science program should select its content from all three areas, giving equal consideration to both the physical and the biological sciences.

When determining what science content should be selected for an elementary science program, there are some guides that can be used to help in making the final selection. One guide is the sciences themselves. They provide the important concepts and conceptual schemes, upon which their organization and development as sciences are based. The sciences help

The science program should include conservation.

indicate which basic science information is most pertinent and desirable. They also suggest ways of thinking and methods of working that will be helpful to children in learning science.

A second guide is the child. Research, although not complete, provides many clues about the mental, emotional, and physical behavior of the child. When selecting science content, consideration must be given to the children's intellectual capacity, their capability for grasping abstract ideas, their curiosity and the resulting questions about themselves and their environment, their aptitude for originality and creativity, and their persistence and attention span.

A third guide is the community. Science content should be selected that will take into account an understanding of the community in which the children live. Such content will vary, depending upon the location and nature of the community. The climate, for example, will play an important part in the selection of the living things to be studied and in learning what the effects of this climate will be upon the living things. Selection of content should also vary according to whether the community is industrial or rural and whether the local terrain is seashore, mountain, plain, or desert. Even though the content will vary among communities, the key concepts learned will still be constant.

The fourth guide is the elementary curriculum itself. The science program should be correlated wherever possible with the rest of the elementary curriculum. Social studies, language arts, mathematics, music, and art all are concerned with understandings that are equally important to science.

The science content, then, should be such that it both reinforces and is reinforced by the learnings indigenous to the other programs of the elementary school.

A final recommendation about the selection of science content is that the science program should also plan to include content involving the areas of health, safety, and conservation. Some schools prefer to teach these areas separately so that they are independent of the science program. Others incorporate these areas into the science program, but take them up as separate topics. Still others prefer to correlate these areas with the relevant science content, based on the assumption that more effective learning will take place when there is a direct association between these areas and the basic science information as it is being learned. Thus, safety and safety rules are learned when the children are studying such topics as machines, electricity, and fire and fuels. Conservation is taken up when the children learn about animals, plants, soil, water, and the earth's natural resources. Similarly, health and nutrition are incorporated when the body is being studied.

Prerequisites of an Effective Elementary Science Program

In recent years a large number of science programs for the elementary school have been emerging. These programs are the result of cooperative efforts of classroom teachers, supervisors, administrators, and science specialists.

There is a tremendous contrast between these newer science programs and the earlier programs. Sometimes the older programs were nothing more than skeletal courses of study, consisting usually of an outline of the chapter titles of the elementary science textbooks being used at the time. The more ambitious of the earlier programs listed the science topics and subtopics to be taken up in each grade, and then included a number of suggested activities or references that the teacher or children could use when studying these topics in class.

Usually, however, science programs did not exist in elementary schools, and each teacher taught science as she wished. Materials and equipment were often unavailable. There was no one the teacher could turn to for help.

Although the teachers were urged to teach science, no time was allocated in the daily program for science. When science was taught, usually the same popular topics such as air, weather, magnets, and plants were taken up in grade after grade so that the material became highly repetitious, boring, and distasteful to the children.

In contrast, the newer programs are rich in science content, providing a wealth of basic science information related to the children's environment. An abundance of learning activities are included in the program. These activities are directed specifically at giving the children an opportunity to investigate and explore so that effective learning of basic science information takes place. Desirable behaviors that may emerge from the learning

activities are often listed. Provision is made for all kinds of learners: slow, average, and fast. Teachers are supplied with source materials and with equipment. Competent supervisors or specialists are available for assistance.

Science programs may vary somewhat in the scope and sequence of their science content, in the learning activities they include, and in the teaching format they use. However, all programs should meet the following prerequisites, if they are to be effective and successful.

PLANNING

A science program should be planned. When science was first taught in the elementary school, and for some time thereafter, there was no such thing as a planned science program. Science learning was organized around incidents that occurred in the classroom. If a child brought a magnet, whistle, unusual-looking rock, queer insect, or pretty leaf into class, a lesson or unit in science was developed around the incident. Often the lesson was quite brief and ended the same day. Usually this kind of lesson tended to stress identification, nomenclature, and the learning of facts rather than major science concepts. If there were no incidents, there were often no lessons in science.

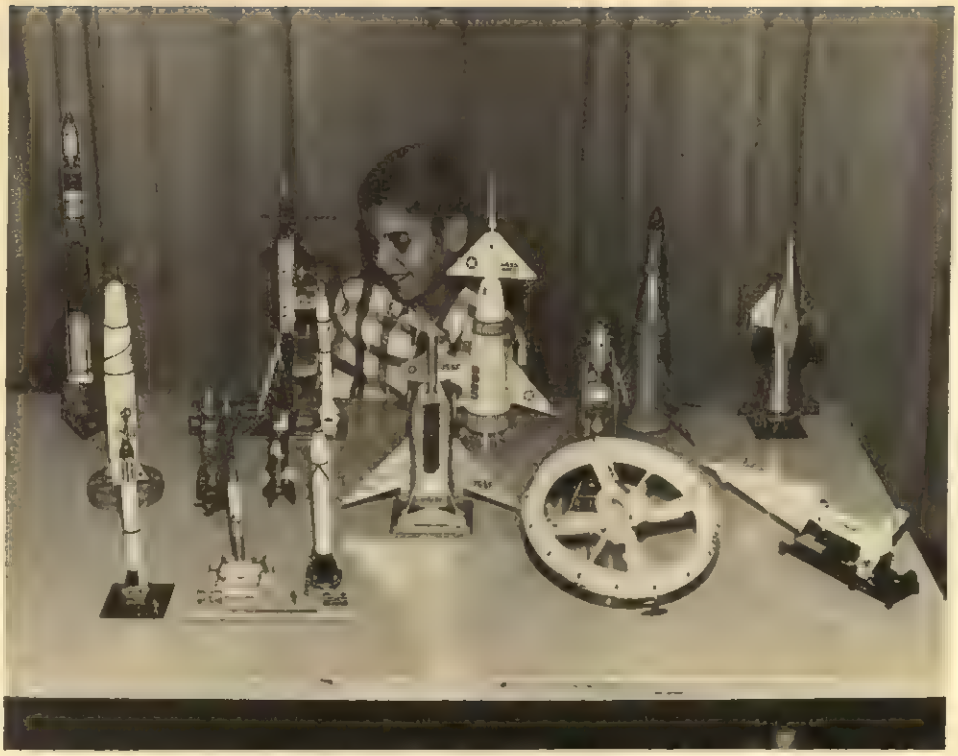
There is no question that incidents arising in the classroom can be a tremendous motivating experience for the children. Under the direction of experienced and skillful teachers with a good science background, such incidents can be used to produce excellent teaching and learning. However, incidents alone are not sufficient to ensure an adequate science program for the elementary school. Nor would the teachers even think of teaching other areas in the elementary curriculum solely on this basis.

One of the most significant forward trends in science education today is the general agreement that the science program should be planned and structured, just as the programs in the other areas of the elementary school curriculum are planned and structured. A planned program not only provides a steady progression of science learning in all grades, but also gives the teacher a definite background and framework of basic science information with which to work in the classroom.

A properly organized program will not discourage incidents that occur, but rather will welcome them as an additional means for producing more effective learning in the classroom. In fact, a planned program now makes it possible for the teacher to create deliberately the kinds of incidents that will instill in the children a desire for exploration and investigation. And when unusual or important incidents do arise, such as sending a satellite or astronaut into space, the planned program can be flexible enough to provide time for these incidents to be taken up in detail.

A planned program should provide for and be guided by the interests of the children. An effective program takes into consideration the children's interests and uses them to motivate learning in science. At the same time it permits the children to help plan and carry out the daily and long-range work in science.

The planned program, when properly organized and administered, can-



The science program should welcome incidents that arise.

not restrict or limit the elementary teacher's initiative and freedom of operation in the classroom, even if the program is structured in great detail, with a comprehensive course of study or curriculum guide, and with well-defined teaching units. In fact, it is a common axiom that the more intensive and detailed the planning is, the greater opportunity there will be for the children to conduct true scientific investigations and explorations.

When planning a program there is freedom for grade placement of science topics between schools. A science topic assigned to a third grade in one school can be allocated to a fourth grade in another school, if the teachers so desire. All teachers can have a choice in the selection of the learning activities they may use to teach for the basic science information to be learned. Teachers may also delve deeper into a unit, if they so prefer. There is ample opportunity to provide for individual differences within the classroom. There can even be allowance for variation in the time of the year when the science topics are taken up. Some teachers prefer to study plants in the spring whereas others prefer to study plants in the fall when the leaves are turning color. Many programs even provide some free time within the school year so that teachers and pupils can work or study on some science projects of their own choice.

A COORDINATED PART OF A K–12 SCIENCE PROGRAM

Science in the elementary school should be planned and coordinated so that it is part of an overall K–12 science program. In this way haphazard

teaching, unnecessary repetition, overlap, and flagrant omissions are eliminated. Instead, a steady progression of learning takes place at each grade level, building upon knowledge from previous grades and leading to further knowledge in the following grades. The basic science information to be learned will proceed steadily from the very simple to the abstract, as the children grow in maturity. In addition, the children will have an opportunity to grow steadily in the development of desirable behaviors and to acquire gradually experience in solving problems, thinking critically, and utilizing effective methods of working.

CORRELATION WITH THE ELEMENTARY CURRICULUM

The correlation of the science program with the rest of the elementary curriculum has already been discussed in detail in Chapter 1, under the broad goals for the elementary science program, as well as earlier in this chapter, when possible guides to be used in selecting science content for the science program were suggested. Care should be taken, however, when correlating science with the rest of the curriculum, that the learning of science is not lost in the process. Real science learning cannot take place in a combined social studies-science unit on "Communications," when teachers take up the social aspects in great detail and merely talk about the science portion. Moreover, although it is good educational practice to correlate science when possible with the rest of the curriculum, it is also impractical and unwise to insist that all science be integrated with other areas. There are many phases of science that are learned best alone. Also, there are times where it is more logical to integrate the other areas with science rather than integrate science with the other areas.

SCOPE AND SEQUENCE

The science program should have scope and sequence. *Scope* refers to the content in the program, and *sequence* refers to the grade level or levels where the content will be allocated. The science program should be broad in scope so that the children will have ample opportunity to learn major concepts and basic principles that affect all the principal aspects of their environment. These broad understandings should be drawn from all areas of science, and their introduction should begin as early as kindergarten, then developed and expanded through the elementary grades. This will help enable the children to acquire a greater understanding of their environment, of how man strives to use and control his environment, of how living things adapt and adjust to their environment, and of how living things are or may be interdependent and interrelated.

There is increasing agreement about the scope of the science content to be taught in the elementary school, as demonstrated by an examination of current elementary science textbooks and science programs. However, this agreement is not true of sequence. Both textbooks and science programs vary widely and consistently in their grade placement of science topics. Some research is being conducted to determine the age levels or grades

where selected science topics or understandings can be taught successfully. The findings generally tend to show that children at any grade level can learn something about all areas of science, provided the concepts are simplified or are within the children's level of maturity and comprehension.

It is becoming more obvious that any attempt to develop one universal science program, with a rigid or fixed grade-placed sequence, is virtually impossible. Children can and do differ widely in ability between schools in the same community, and also between schools of different communities. It is not uncommon for a teacher to find that the children differ in ability from year to year even in the same grade. Moreover, the growing conviction that elementary school children can learn more science than was hitherto believed possible has resulted in increasing the science content being introduced into the science program.

Yet it is equally obvious that some kind of sequence is necessary. In every science topic the concepts range from the very simple to the more complex. Some topics involve concepts that are more abstract than others. Whatever topics are assigned to a lower grade level will contain concepts that cannot be developed fully, regardless of the children's ability. Further development of these concepts will be needed at a higher grade level to ensure complete comprehension and learning.

Earlier science programs attempted to solve the problem of sequence by requiring the same topics to be taught each year, with provision for a steady spiral of concepts to be developed in each grade, progressing from the easily understandable to the more difficult. When the topics were narrow and unrelated, such as magnets, static electricity, soil, sound, and so forth, the science programs proved to be highly unsatisfactory for everyone.

To get as wide a scope as possible, so many of these narrow, unrelated topics had to be included in each grade that the teacher could not find enough time to teach satisfactorily all the science that was required for the grade. This would lead to gaps in the children's science learning. Often it was difficult to find enough concepts on a single, narrow topic for the program so that some could be distributed for each grade. It would be difficult and perhaps futile, for example, to collect enough concepts on the topic of magnets so that a satisfactory number could be allocated in each grade from kindergarten through grade 6. This would necessarily make the treatment of magnets in each grade highly superficial. No sooner would the teacher initiate a unit on magnets than she would have to stop because she had taken up all the concepts that were assigned to her grade level. If the teacher did succumb to the interest and pleas of the children to learn more about magnets, this procedure would create a hardship upon teachers in succeeding grade levels.

Most science programs today have either bypassed or abandoned this tight, grade by grade, spiral of narrow topics and have adopted a much looser spiral pattern. This has been accomplished by incorporating the individual topics under broader, related content areas. In this way, although a major area is taken up each year, an individual topic—such as sound or magnets—is taken up only periodically.

As a result, the grade placement of science topics in these programs varies, depending upon the basic philosophy of the different schools or school systems and upon the number of broad content areas that make up the program. Some schools organize their science content so that a topic is taken up three times during the kindergarten through grade 6 period: the sequence is as follows: once in grades K–2, a second time in grades 3–4, and a third time in grades 5–6. Other schools take up a science topic just twice: in grades K–3 and again in grades 4–6. Still other schools have no regular pattern, but will take up a topic two, three, or even four times, depending upon the amount of science content entailed in the topic.

Some schools assign specific science units to the kindergarten. Others suggest only that the kindergarten teacher scrutinize her daily program of activities closely for science implications, then plan accordingly for experiences in science. Still others provide for both planned science units and incidental activities arising from the questions that the children will ask.

Regardless of which grade-placement plan a program uses, in all cases individual topics are now taken up periodically from kindergarten through grade 6. This plan enables each topic to be explored in greater depth and more satisfying detail. As a result, not only is there a greater opportunity for more major understandings to emerge each time, but also relationships between these understandings can now develop more easily, in a number of ways and from more than one direction. Programs such as these make possible a real spiral of learning. When a topic recurs in a spiral, new and more difficult concepts are built upon previously learned concepts. In each

Learning science in kindergarten.

Learning cause-and-effect relationships.

case previous knowledge about the topic is reviewed briefly, and then this knowledge is extended further. Repetition thus serves to associate the old concepts with the new.

Exact grade placement of basic science information in the science program can and should be an individual concern, left to the decision of those working with the program. The grade placement may vary from school to school within the same community, or from community to community. Most concepts allocated for a specific grade level can be learned with equal success in one grade level immediately above or below the specified grade. However, difficulties are more likely to arise when the difference in allocation of concepts involves two or more grade levels.

The following suggestions may be helpful in organizing the sequence of topics and concepts for a science program. To begin, many individual topics can be related and incorporated to form broader content areas. Magnetism, static electricity, and current electricity, for example, can be combined to constitute one content area. Similarly, machines can be combined with friction, heat with fire and fuels, water with weather and climate, soil with rocks and minerals, and air with planes and space travel.

Some science topics might be placed in the same grade because they are all concerned with a common concept or theory. For example, an understanding of the theory of molecular motion will explain many of the phenomena of heat, sound, magnets, and physical states of matter. If the molecular theory is allocated to a certain grade level, the placement of these topics in the same grade level may save needless repetition and at

the same time ensure a greater understanding of the theory because it was approached from different directions. Also, when the atomic theory is allocated to a certain grade, static and current electricity could also be profitably placed in the same grade.

Allocation of topics and concepts will also depend upon the children's growth in ability to understand cause-and-effect relationships, to recall and rationalize, and to grasp abstract ideas. In some programs the science for kindergarten through grade 2 is primarily devoted to making the children aware of science phenomena in their environment. Science in grades 3–4 is directed toward promoting the understanding of simple cause-and-effect relationships. In grades 5–6 the more complex or abstract concepts involved in the cause-and-effect relationships are developed. For example, in the first spiral the children may learn that water can disappear or go into the air, where it becomes an invisible gas called water vapor. In the second spiral the children will explore the factors that affect evaporation, such as heat, wind, surface area, and so on. In the third spiral the children will learn the molecular theory and how evaporation and the factors affecting evaporation can be explained according to the molecular theory. Thus the children develop awareness in the first spiral, deal more with the effects in the second spiral, and devote more time to the causes in the third spiral.

One should keep in mind the facts that there is no sharp delineation in function or intent between spirals and that it is not obligatory to always have the same number of spirals for each content area. The difficulty of the concepts will be a deciding factor. Thus it may be feasible in some cases to teach for the development of an awareness of science phenomena in the second or even in the third spiral. By the same token, causes of some phenomena can be learned in the first spiral. In all cases the science program should attempt to have the children learn key concepts and major understandings as early as possible.

Finally, the science program should evaluate its sequence continuously, not periodically. Only if the effects of a particular sequence on learning in the classroom are carefully observed, and the sequence constantly reshuffled whenever the grade placement appears to be unsuited, can a well-organized and effectively structured science program emerge.

BALANCE

The science program should have balance. A well-balanced program should provide opportunities for the children to explore regularly in each of the three major areas, which include the earth and the universe, living things, and matter and energy. Equal emphasis should be given to the physical and the biological sciences in the overall program. A balance in the length of units might be desirable so that some would be long and others would be shorter. There should also be balance in the number of units taught each year. The present trend is toward the adoption of a relatively small number of units per year, however, with provision for greater depth in science content.

EMPHASIS ON CONCEPTS

The science program should be concerned with more than technology. Too many science programs place undue emphasis upon how science helps us in our daily life, and not enough emphasis upon the underlying science concepts. The result is that the children, our future adult citizens, acquire a distorted image of science. They tend to view science primarily as an agent for developing useful gadgets and appliances, and thus making their lives more pleasant and comfortable. They never learn, or else lose sight of, the fact that science is a way of life—an exciting open-ended process that man uses to explain the natural phenomena of the world in which he lives.

VARIETY OF ACTIVITIES

The children should have ample opportunity to use a large number of diversified activities when learning science. They should have a chance to do experiments and demonstrations, read, give reports, participate in discussion, take field trips, listen to resource persons, use audio-visual aids, do research, and work on projects. There should also be activities that reinforce learning for the slow learner, and activities that challenge and extend the knowledge of the fast learner. At the same time, opportunities should be provided for children to investigate incidents or problems that arise and are not part of the planned program.

PROVISION FOR NECESSARY MATERIALS

It is useless for a science program to include "doing" learning activities unless the necessary supplies and equipment are made available. Thus an annual budget must be allotted to the elementary school for science materials so that the science program can function successfully. Moreover, each classroom should have its own science library, and the school library should have an adequate selection of science books. Provision must also be made for easy accessibility to films, filmstrips, and television programs.

HELP AND ENCOURAGEMENT FOR THE TEACHER

In a planned science program the elementary teacher must be familiar with the basic science information in the five major fields of astronomy, biology, chemistry, geology, and physics. This knowledge requires a larger science background than most elementary teachers receive in their preservice training. It is also an accepted fact that many teachers are reluctant to teach science because their science background is so limited. These teachers need help, if the science program is to be effective.

This assistance can be furnished in many ways. Professional books, sourcebooks, and curriculum materials can be made available. In-service education in science itself, in the form of courses or workshops, can be provided. Many of the larger school systems are beginning to employ science consultants. These persons, both proficient in science and in working with children, can do much to strengthen the science program and the morale of the teachers. They can plan with the teachers, suggest additional learning

activities, frequently do demonstration teaching, locate and order equipment, and conduct local workshops.

Some school systems employ full-time science consultants or supervisors. They are given either a limited teaching schedule or none at all so that they can spend most of their time working on the program or with those teachers who need help. Other school systems may have a consultant on a part-time basis. Sometimes school systems use a competent junior high school teacher, who is given only a half-time teaching load so that the rest of the time can be devoted to the elementary teachers. Sometimes they use a science-minded elementary school teacher, letting someone else take over her class part of the time while she works with the other teachers in her building. Some school systems have a science educator come periodically to furnish advice and assistance to the teachers. Planned science programs in the elementary school are still comparatively new, and the position of elementary science consultant or supervisor is even newer. The trend, however, seems to be quite definitely toward the increased use of full-time consultants.

SUFFICIENT TIME

There is definite agreement that science should be a regular part of the daily program, and have adequate time within the program. Both interest and learning are lost if science is scheduled only once or twice a week. Opinions vary, however, as to how much time should be allotted to science, daily or weekly. The general feeling is that more time should be devoted to science in grades 4–6 than in K–3. Some schools require that a definite amount of time be devoted daily to science. One recommended time allotment is 20–30 minutes per day for K–3 and 30–40 minutes per day for grades 4–6. Some schools set aside three days a week for science, with an average of 40–60 minutes per day. Other schools merely stipulate a definite amount of time per week, usually 120–180 minutes, and let the teacher allocate the time as needed throughout the week. Still other schools require that science be taught, but leave the time allotment to the discretion of the individual teacher.

CONTINUOUS EVALUATION

To be effective the science program should be evaluated continually, with everyone involved in the program participating in the evaluation. The scope and basic science information can be examined for corrections, additions, or deletions. The sequence must be evaluated to ensure optimum grade placement. Activities should be scrutinized critically to see if they are achieving maximum learning. Newer, more productive activities should be substituted as they appear in text, reference, and resource books. Initiating activities may be evaluated for greatest possible motivating and problem-raising potential. Even the evaluation techniques themselves should be examined regularly to see if learning is taking place in the classroom.

Teachers work cooperatively to develop a science program.

Organizing the Science Program

A WELL-ORGANIZED science program will make a large difference in the amount and kind of science being taught and learned in the elementary school. There are several factors that affect the successful development of an effective science program. The manner in which the science program is organized will influence its success or failure. A democratic and cooperative procedure, where the teachers all take an active part in creating the program, will greatly enhance the likelihood of the program's acceptance and widespread use. Furthermore, it is commonly acknowledged that no crash program has ever had a long or satisfactory life. There is a direct relationship between the success of a program and the time and effort that was spent in developing it.

Finally, leadership is absolutely necessary. Although the teachers are willing to work hard, spending many hours, on a science program, this work is not enough. Administrators must assume leadership in initiating the program. They must stimulate the teachers, encourage the emergence and growth of leadership from the ranks of the teachers themselves, guide the teachers in working cooperatively and effectively, obtain expert assistance and resource persons, and provide materials wherever and whenever needed.

The following is a description of one of the several ways that have proved to be highly successful in organizing an effective science program in the elementary school.

DEVELOPING A SCOPE AND SEQUENCE CHART

The first step in setting up a science program is the development of a scope and sequence chart. This chart development requires a science curriculum committee, consisting of teachers who are experienced or interested in teaching science. An ideal committee for a K–6 program would consist of one or more representatives from each grade. These teachers would then meet regularly with the rest of the teachers in their grade, report on the work and progress of the committee, and present committee proposals for suggestions, recommendations, approval, or disapproval.

The committee should also have one or more representatives from the junior and senior high schools, especially if the program is to be part of an overall K–12 program. In this way the junior and senior high schools will be informed about what the elementary school is doing. They can learn what science content is being considered for the elementary program and utilize this information when organizing or reorganizing their own science programs. Besides, the junior and senior high school representatives can be of great help to the committee in selecting science content, suggesting suitable activities, and recommending needed materials.

The committee should also have guidance and leadership from a science supervisor, if one is available, or from a science educator. Either person can help in many essential ways, such as suggesting or obtaining professional literature, other scope and sequence charts, courses of study or curriculum guides, materials, and so forth. He will often perform a valuable service by acting as a moderator or referee when the discussion becomes heated.

The committee should meet regularly; bimonthly meetings seem to work well. The progress of the committee will increase manifold if the members are given released time from their teaching duties so that they can devote sufficient time and effort to the undertaking. Many committees have either failed or limped along slowly because meetings were held after school, when the teachers were tired from their long day's work, or else on Saturdays, when many teachers resent the infringement upon their own time.

The committee should work upon scope first. When doing so, the committee might think in terms of not only selecting topics, but also in terms of agreeing to the minimum amount of basic science information the children should know by the time they leave the sixth grade. In this way all the children from different elementary schools in a school system can enter the junior high school with a comparatively equal science background and an equal opportunity to succeed in the junior high school science program. Reasonably uniform preparation of elementary students will also help the junior high school teachers in conducting or planning their science program. It would be wise for the committee to agree only on the *minimum* basic science information. This information would include the concepts and conceptual schemes that all the children, regardless of ability, should know. Each teacher in each school may go as much further as she likes or can with the fast learners.

When selecting content the committee should consult every means available. It can go to the literature and recommendations of science educators, analyze the contents of elementary science textbooks, consult professional scope and sequence charts, and examine other courses of study. The science supervisor or consultant may be able to inform the committee of trends in the scope of the science program throughout the country. In its selection of science content the committee should also consider the children's interests and the local scene or community.

The committee would now select the topics it thinks should be included in the science program. Related topics would be combined and incorporated to form broader content areas, in the manner suggested earlier in this chapter when discussing scope and sequence as a prerequisite of the science program.

After the topics have been selected, the next step would be to make a simple outline of all the key subtopics that should be included under each topic. It would be helpful to arrange the subtopics so that they lend themselves to a logical sequence of learning. There are many such arrangements possible, all equally effective, so that arrangement can be a matter of personal preference by the committee. One way to facilitate the work of making outlines is to have the individual committee members assume the responsibility for constructing outlines for specific topics. These outlines can then be evaluated by the committee as a whole for additions, corrections, or omissions. When the committee has agreed upon all the topics and their outlines, which will constitute the scope of the science program, the members can bring the plan to the teachers of their respective grades for examination, comments, and subsequent approval.

With the acceptance of the scope of the program, the task of grade placing the science content begins. It is really a task because so little research has been conducted in this area. Consequently, until valid and reliable findings become available, the committee will have to rely upon common sense, the previous experiences and recommendations of others, and trial and error.

The rest of the elementary curriculum should be taken into consideration when grade placing the science topics. For example, if the social studies program is teaching the topic of communications quite successfully in one or more grades, it would seem desirable to see if sound and light could be allocated successfully in the same grades. The choice of basic elementary science textbooks will also make a difference in grade placement, especially if the school system prefers using a single series. If, in this series, the topic of heat is taken up in the second- and fifth-grade texts, it might be feasible to try to place the topic in these two grades as well, so that the children can take full advantage of the science content and activities contained in the textbooks. With multiple textbooks, of course, there will be much more freedom in coordinating the sequence of the program with that of the textbooks.

The committee should always keep in mind that the basic idea in a spiral sequence pattern is for the learnings in a lower spiral to be reinforced and

extended further in the next spiral. In all cases there is a logical progression from simple to more complex concepts. An example of how the study of machines could be taken up in a K–3, 4–6 spiral sequence may be helpful. In the lower spiral the children would learn that all machines make man's work easier in five different ways: they can transfer a force, they can make things go faster or slower, they can make things move in a different direction, they can usually make things move over a larger or smaller distance, and they can enable us to use less force while the machines give us more force. Machines can do more than one of these things at one time, but they can not do all five of these things at one time. Every machine is made up of one or more of six simple machines. The children in the lower spiral can thus study all six of these machines at one time and see how the five things that the machines can do will apply to each machine. The children are able to develop a qualitative understanding that the less effort exerted, the greater the distance the effort will have to move, and vice-versa. The children can even become familiar with simple kinds of compound machines.

In the upper spiral the children will now take up each machine in detail and go much deeper into the concepts developed in the lower spiral. Mechanical advantage can be introduced, as well as quantitative measurements.

The example just described is by no means complete. It does not include the correlation or incorporation of the study of friction with the study of machines. Nor is there any mention of the concept of energy and how it can be transformed. But the example does serve to indicate how in the lower spiral certain concepts can be allocated that are well within the comprehension of the children, and how in the upper spiral the concepts are reinforced and extended further while new concepts are also introduced.

When the committee has completed the grade placement, in the form of a scope and sequence chart, the members should then go back again to the teachers in their own grades. This time the teachers in each grade will have to consider a list of topics for the grade, as well as the completed, overall plan. No further steps should be taken until there is general approval of the chart, both as to scope and sequence. It will be understood, of course, that the chart is tentative and can be revised whenever necessary. Changes are usually made either when a comprehensive curriculum guide is being developed or after the new program has been tried out in the classroom and evaluated.

SAMPLE SCOPE AND SEQUENCE CHART

Tables 3–1 to 3–15 comprise an example of a scope and sequence chart that could be used for a K–6 elementary science program. As shown in Table 3–1, the content has been grouped under four broad areas: "Introduction to Science," "Living Things," "Earth and Universe," and "Matter and Energy." The areas are subdivided into fourteen major topics. The general grade placement of these major topics is as follows: one half of

them are allocated to grades K, 2, 4, and 6; the other half are allocated to grades 1, 3, and 5. Because only seven topics are assigned to a grade, there is ample opportunity to develop depth in each grade and breadth for the entire program.

Table 3–1, the first portion of the chart, gives an overview of all the areas and major topics, together with their allocation by grades. Tables 3–2 to 3–15 are devoted to the major topics. The subtopics for each topic are indicated, along with the grades where these subtopics have been placed. It should be noted that "Health" is taken up here as a separate topic whereas "Conservation" appears as an appropriate subtopic throughout the program.

TABLE 3–1. K–6 Scope and Sequence Chart

Area and Major Topics	Grade Level K	1	2	3	4	5	6
I. *INTRODUCTION TO SCIENCE*		x		x		x	
II. *LIVING THINGS*							
A. Animals	x	x		x		x	
B. Health	x		x		x		x
C. Plants	x		x		x		x
III. *EARTH AND UNIVERSE*							
A. Air, planes, and space travel		x		x		x	
B. Astronomy	x		x		x		x
C. Earth		x		x		x	
D. Water, weather, and climate	x		x		x		x
IV. *MATTER AND ENERGY*							
A. Changes in matter and energy			x		x		x
B. Heat, fire, and fuels		x		x		x	
C. Light	x		x		x		x
D. Machines and friction		x		x		x	
E. Magnetism and electricity	x		x		x		x
F. Sound		x		x		x	
TOTAL	7	7	7	7	7	7	7

TABLE 3–2

KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3
	A. What science is. B. How science helps us. C. Characteristics of scientists. D. Scientific attitudes (simple).		A. Branches of science. 1. Biology. 2. Chemistry. 3. Physics. 4. Astronomy. 5. Geology. B. History of science. C. Pure versus applied science. D. How scientists work. 1. Scientific methods. 2. Scientific attitudes.

TABLE 3–3

KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3
A. Animals around us (including pets). B. Identifying animals. 1. Sound. 2. Size and shape. 3. Color. 4. Habits. C. Needs of animals. 1. Water. 2. Food.	A. How animals are alike and different. 1. Movement and growth. 2. Homes. 3. Sounds. 4. Reproduction. B. What animals need to live. C. Care of animals and their young.		A. Adaptation to environment. 1. Effect of seasons and weather on food, homes, coats, hibernation, migration. 2. Protective coloration. C. Defense mechanisms. D. Helpful and harmful animals. E. Insects. 1. Physical description. 2. Where they live.

Introduction to Science

Grade 4	Grade 5	Grade 6
	A. How scientists work. 1. Scientific methods. 2. Scientific attitudes. 3. Scientific abilities and skills. B. Tools of science. 1. Vocabulary and terminology. 2. Measurement and computation. 3. Professional meetings and publications. C. Economic importance of science. D. Great men in science.	

Living Things: Animals

Grade 4	Grade 5	Grade 6
	A. Classification. 1. Vertebrates. 2. Invertebrates. B. One-celled animals. C. Selected (indigenous) animals. 1. Physical description. 2. Where they live. 3. What they eat. 4. Reproduction. 5. How they grow and move. 6. Helpful and harmful. D. Man's control of animals. 1. Selective breeding. 2. Hybrids. E. Interdependence of plants and animals. 1. Balance of nature. 2. How man has disturbed this balance.	

Kindergarten	Grade 1	Grade 2	Grade 3
			3. What they eat. 4. Reproduction. 5. Life cycles. 6. Social insects 7. Helpful and harmful insects.

Table 3-4.

Kindergarten	Grade 1	Grade 2	Grade 3
A. Good eating habits. B. Cleanliness. C. Rest and sleep. D. Care during illness.		A. Parts of body and functions (simple). B. Care of body and its parts. 1. Need for cleanliness. 2. Need for rest and sleep. C. Sickness and disease. 1. Good health habits. 2. Preventing the spread of contagious diseases.	

Table 3-5

Kindergarten	Grade 1	Grade 2	Grade 3
A. Plants around us. B. Learning about and collecting parts. 1. Leaves. 2. Flowers. 3. Fruits. 4. Nuts.		A. Parts and function of plants (simple). 1. Roots and stems. 2. Leaves. 3. Flowers and fruits. 4. Seeds.	

Grade 4	Grade 5	Grade 6
	3. Man's attempts to restore balance of nature. F. Conservation. G. Prehistoric animals (including evolution).	

Living Things: Health

Grade 4	Grade 5	Grade 6
A. Food. 1. Purpose. 2. Different kinds. B. The Four Basic Food Groups. 1. What they contain. 2. Function. C. Need for balanced diet. D. Proper eating habits.		A. Human body. 1. Structure of systems. 2. Function of systems. B. Community health and sanitation. 1. Germ theory of disease. 2. Symptoms of common diseases. 3. How communicable diseases spread. 4. Controlling communicable diseases. 5. Immunization. 6. Sanitary measures. 7. Good public health habits.

Living Things: Plants

Grade 4	Grade 5	Grade 6
A. Classification of plants. 1. Land and water. 2. According to climate. 3. Annuals, biennials, and perennials. 4. Flowering and non-flowering plants.		A. Parts and function of plants. B. Life processes of plants. 1. Photosynthesis. 2. Respiration. 3. Transpiration. 4. Reproduction (including hybrids and selective breeding).

Kindergarten	Grade 1	Grade 2	Grade 3
5. Seeds. C. Seeds become plants. D. Uses of plants.		B. Conditions necessary for growth. 1. Air. 2. Water. 3. Light. 4. Proper temperature. 5. Proper soil. C. Ways of growing plants. 1. Seeds. 2. Bulbs. 3. Roots. 4. Stems. 5. Cuttings or slips. 6. Leaves. D. Seeds. 1. Parts. 2. Germination and growth. 3. How seeds travel.	

Table 3-6

Kindergarten	Grade 1	Grade 2	Grade 3
	A. Air is real. 1. Occupies space. 2. Has weight. B. Air is all around us. C. Air has pressure. D. Wind is moving air. E. Vehicles that travel through the air.		A. Air. 1. Is part of the earth. 2. Where air is found. 3. The atmosphere. B. Planes. 1. Propeller and jet. 2. Parts and function. C. Rockets. 1. Kinds. 2. Function. D. Satellites and space travel.

Grade 4	Grade 5	Grade 6
B. Effect of soil, water, air, and light on growth. C. Effect of seasons, weather, and climate. D. How plants help and harm us. E. Conservation. F. Prehistoric plants.		5. Tropisms. C. Trees. 1. Structure. 2. Conditions necessary for growth. 3. Kinds. 4. Reproduction. 5. Uses. 6. Conservation. D. Fungi. 1. Bacteria and yeasts. 2. Molds and mushrooms. 3. Helpful and harmful fungi.

Earth and Universe: Air, Planes, and Space Travel

Grade 4	Grade 5	Grade 6
	A. Air. 1. Properties. 2. Composition. B. Earth's atmosphere. C. Air pressure. D. Principles of flight. 1. Bernoulli's principle. 2. Newton's law of action and reaction. E. Planes. 1. Propeller versus jet. 2. Parts and function. 3. Helicopters. F. Rockets. 1. Kinds and function. 2. Satellites.	

Kindergarten	Grade 1	Grade 2	Grade 3

Table 3-

Kindergarten	Grade 1	Grade 2	Grade 3
A. Awareness. 1. Sun. 2. Moon. 3. Stars. B. Day and night. C. Clear and cloudy days. D. Changes in seasons.		A. Sun. 1. Is far away. 2. Is hot. 3. Gives heat and light. B. Earth. 1. Is round. 2. Rotates around sun. C. Day and night. D. Shadows. E. Moon. 1. Is round. 2. Rotates around earth. 3. Reflects light of sun. 4. Phases.	

Table 3-E

Kindergarten	Grade 1	Grade 2	Grade 3
	A. Land formations. B. Water formations. C. Rocks. D. Kinds of soil for growing plants.		A. Soil. 1. Origin. 2. Types. 3. Testing. 4. Enrichment 5. Conservation. B. Soil and water. 1. Cultivation 2. Irrigation. 3. Drainage. 4. Dry farmi C. Natural resources. 1. Coal.

Grade 4	Grade 5	Grade 6
	G. Space travel. 1. Problems of getting into space. 2. Problems of space travel.	

Earth and Universe: Astronomy

Grade 4	Grade 5	Grade 6
A. Sun. 1. Nature. 2. Source of energy. B. Effect of sun on the earth. 1. Heat and light. 2. Day and night. 3. Year. 4. Seasons. 5. Effect on growth and activity of living things. C. Moon. 1. Nature. 2. Motion around earth. 3. Phases. 4. Tides. 5. Eclipses. D. Solar system. E. Difference between planets and stars.		A. Sun and solar system. 1. Gravity, inertia, and orbit. 2. Composition and characteristics. 3. Moons. 4. Comets. 5. Meteors and meteorites. 6. Life on other planets. B. Outer space. 1. Stars. 2. Constellations. 3. Galaxies. C. Astronomical instruments.

Earth and Universe: Earth

Grade 4	Grade 5	Grade 6
	A. History of the earth. B. Earth's crust and layers. C. Types of rock. 1. Igneous. 2. Sedimentary. 3. Metamorphic. D. Minerals. E. Fossils. F. Forces changing the earth's surface.	

Kindergarten	Grade 1	Grade 2	Grade 3
			2. Oil and gas 3. Minerals. 4. Conservation.

Table 3-

Kindergarten	Grade 1	Grade 2	Grade 3
A. Water appears and disappears. B. Sinking and floating. C. Dissolving things. D. Clouds. E. Kinds of weather conditions. F. Effect of weather and climate on living things.		A. Evaporation and condensation. 1. Factors affecting rate. 2. Effect on living things. B. How precipitation is formed. 1. Clouds. 2. Rain. 3. Snow. 4. Sleet. 5. Hail. 6. Dew. 7. Frost. 8. Fog. C. Water cycle.	

Table 3-1

Kindergarten	Grade 1	Grade 2	Grade 3
		A. States of matter. B. Different kinds of matter. C. Different properties of matter. D. Producing changes in matter, such as rusting, burn-	

GRADE 4	GRADE 5	GRADE 6
	1. Weathering—physical and chemical. 2. Erosion—wind, glaciers, water, oceans, etc. 3. Earthquakes, volcanoes, hot springs, geysers, etc. 4. The work of man.	

Earth and Universe: Water, Weather, and Climate

GRADE 4	GRADE 5	GRADE 6
A. Difference between weather and climate. B. Basic factors that determine climate. 1. Temperature. 2. Wind. 3. Humidity. C. Local factors that affect climate. 1. Large bodies of water. 2. Ocean currents. 3. Winds. 4. Altitude. 5. Topography. D. Effect of weather and climate on living things.		A. Evaporation and condensation. 1. Molecular explanation. 2. Factors affecting rate. 3. Effect on living things. B. Weather. 1. Humidity. 2. Precipitation. 3. Air masses. 4. Weather forecasting and instruments. 5. Water cycle. C. Waters of the earth. D. Water. 1. Properties. 2. Water pressure. 3. Sinking and floating. 4. Hard water (including softening). 5. Purification. 6. Conservation.

Matter and Energy: Changes in Matter and Energy

GRADE 4	GRADE 5	GRADE 6
A. Definition of energy. B. Potential and kinetic energy. C. Forms of energy. D. Transformation of energy. E. Sources of energy. F. Solar energy.		A. Structure of the atom. B. Elements. C. Molecules. D. Symbols and formulas. E. Mixtures and compounds. F. Atomic energy. G. Relationship between matter and energy. H. Solutions.

KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3
		ing, decaying leaves. E. Dissolving matter. F. Crystals.	

TABLE 3–11.

KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3
	A. Sources of heat. B. Freezing, melting, and boiling. C. Expansion and contraction (simple). D. Fire. 1. Ways of making fire. 2. Putting out fire. 3. Safety rules E. Kinds of fuels.		A. Expansion and contraction. 1. In solids, liquids, and gases. 2. Exceptions. 3. Uses. B. Temperature and thermometers. 1. How thermometers operate. 2. Fahrenheit and Centigrade scales (simple). 3. Kinds and uses of thermometers. C. Fire. 1. Nature. 2. Conditions for making fire. 3. Conditions for putting out fire. 4. Safety rules. D. Fuels. 1. Kinds. 2. Comparison.

Grade 4	Grade 5	Grade 6
		I. Common chemicals. 1. Acids. 2. Bases. 3. Salts. 4. Oxides. J. Common minerals.

Matter and Energy: Heat, Fire, and Fuels

Grade 4	Grade 5	Grade 6
	A. Molecular theory of heat. 1. Temperature. 2. Expansion and contraction. 3. Changes in physical states of matter. B. Thermometers. C. Methods of heat travel. 1. Conduction. 2. Convection. 3. Radiation. D. Fire. 1. Nature. 2. Flame and smoke. 3. Conditions necessary for making fire. 4. Kinds and sources of fuels. 5. Spontaneous combustion. 6. Conditions necessary to put out fire. 7. Fire extinguishers. 8. Safety rules.	

TABLE 3–12.

KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3
A. Sources of light. B. Colored lights. C. Colored pigments.		A. Sources of light. B. Light travels in straight lines. C. Transparent, translucent, and opaque materials. D. Shadows.	

TABLE 3–13.

KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3
	A. Machines in the home. 1. Different kinds. 2. How they help us. B. Machines outside the home. 1. Different kinds. 2. How they help us. C. How some mechanical toys operate.		A. What machines are. B. How machines help. 1. Change force. 2. Change direction. 3. Change speed and distance. C. Six simple machines. 1. How each one works. 2. How each helps us. D. Friction. 1. What friction is. 2. Decreasing and increasing friction. 3. Harmful and useful effects.

Matter and Energy: Light

Grade 4	Grade 5	Grade 6
A. Spectrum. B. Colored lights. 1. Mixing. 2. Complementary. C. Colored pigments. 1. Mixing. 2. Complementary. D. Rainbows.		A. Nature of light. 1. Visible radiation. 2. Infrared and ultraviolet radiation. B. Speed of light. C. Sources of light. D. Reflection of light. 1. Law of reflection. 2. Mirrors. E. Refraction of light. F. Lenses. G. The eye. H. The camera. I. The microscope and other optical instruments. J. Photoelectric cell.

Matter and Energy: Machines and Friction

Grade 4	Grade 5	Grade 6
	A. Friction. 1. Factors affecting friction. 2. Decreasing and increasing friction. 3. Harmful and useful effects. B. Six simple machines. 1. How each one works and helps us. 2. Machines do not save work. 3. Input and output. 4. Mechanical advantage. 5. Friction affects work (efficiency). C. Multiple machines.	

TABLE 3–14.

KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3
A. Magnets. B. Electricity. 1. Sources. 2. Uses. 3. Safety rules.		A. Magnets. 1. What they are and do. 2. Law of magnetic attraction. 3. Materials the force of a magnet will pass through. 4. Making magnets. 5. Making an electromagnet. 6. Simple compass. 7. Uses of magnets. B. Static electricity. 1. How it is produced. 2. Effects.	

TABLE 3–15.

KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3
	A. Different ways of making sounds. B. Recognizing different sounds. C. Characteristics of sounds. 1. High and low. 2. Loud and soft.		A. Ways of producing sound. B. Nature of sound. C. Characteristics of sounds. 1. Pitch. 2. Intensity. 3. Quality. D. How sound travels.

Matter and Energy: Magnetism and Electricity

Grade 4

A. Simple electric circuit.
   1. Parts.
   2. Conductors and nonconductors.
   3. Switch.
   4. Short circuit.
   5. Fuse.
   6. Safety rules.

B. Electromagnets.
   1. Making an electromagnet.
   2. Increasing strength of electromagnets.
   3. Magnets versus electromagnets.
   4. Uses.

Grade 5

Grade 6

A. Static electricity.
   1. Ways of producing.
   2. Nature of static electricity.
   3. Law of electrostatic charges.
   4. Attracting neutral objects.
   5. Lightning and thunder.

B. Electricity.
   1. Nature of electricity.
   2. Wet and dry cell.
   3. Storage battery.
   4. Series and parallel circuits.
   5. Simple generators and motors.
   6. Alternating current (A.C.) and direct current (D.C.) (simple).
   7. Uses.
   8. Safety rules.

C. Electronics and communication.
   1. Radio.
   2. Radar.
   3. Television.

Matter and Energy: Sound

Grade 4

Grade 5

A. Sound.
   1. Nature.
   2. Sound waves and molecular motion.
   3. How sounds travel through solids, liquids, and gases.
   4. Speed of sound.
   5. Echoes.

B. Music.
   1. Music versus noise.
   2. Characteristics of a musical tone.

Grade 6

Kindergarten	Grade 1	Grade 2	Grade 3
	3. Difference in quality. D. Producing sounds. 1. String instruments. 2. Wind instruments. 3. Percussion instruments.		E. Sounds travel through solids, liquids, and gases. F. Echoes. G. Music.

Grade 4	Grade 5	Grade 6
	C. String, wind, and percussion instruments. 1. Kinds. 2. Ways of producing musical tones. 3. Changing pitch, intensity, and quality. D. The ear. E. The voice.	

DEVELOPING A CURRICULUM GUIDE

Developing a curriculum guide is the next step in organizing a science program. The nature of the guide will vary, depending upon the preference of the school system. It can be kept to a minimum or expanded in great detail. In either case the guide should never be so rigid that it discourages individual initiative or resourcefulness in the teacher's work in the classroom. The more effective guides, however, do include specific basic science information to be learned by the children, suggested learning activities, necessary materials, and appropriate references. Many also include possible initiating activities, anticipated pupil questions or problems, additional activities for slow and fast learners, and suggestions for the evaluation of both learning and behavior.

Once the format of the curriculum guide has been approved and accepted, the procedure would then be to involve as many teachers as possible in working on the guide. The ideal situation is to have all the teachers participate, because the guide will then be *theirs*—something that they have approved, worked on, and developed. However, the teachers must first become completely familiar with the format of the guide and the methods that can be used to prepare its contents. The supervisor or consultant can meet with the teachers for this purpose, either all at one time or in smaller groups if necessary. Sample curriculum guides and courses of study with formats similar to the one that has been adopted could be made available for study and discussion. The supervisor could also prepare a brochure on how the work could be planned and organized, containing the kind of instructions described in Chapter 5, "Planning for Science in the Classroom." As many meetings as necessary should be held with the teachers until they all are completely familiar with the method for developing the guide.

At this time committees may be appointed which can be of great service. Several groups might work on individual science topics, selecting the minimum basic science information that will be included in each topic, then apportioning the concepts among the grades. Their results should be evaluated by the committee, especially those members from the junior and senior high schools, for accuracy of content, omissions, and suitability of grade placement.

At this point the teachers themselves can begin working on the guide. First-grade teachers could develop the guide for the first grade, second-grade teachers for the second grade, and so on. Smaller groups of teachers within each grade might be assigned to work on individual topics of units, so that the task for any one group would not be too great. As each topic or unit was completed, teachers in the same grade and also in other grades would examine it for gaps, overlap, and needless repetition. The science committee would then go over it for final approval. In this way active participation of all, or as many teachers as possible, would be obtained.

One final step is necessary to ensure successful use of the guide, and that is to familiarize all the teachers with the contents of the guide or at least

Teachers can demonstrate science concepts to other teachers.

the contents for their particular grade level. The reason is obvious. If a group of teachers from one grade worked on a single topic, these teachers will have become very familiar with the basic science information, activities, and materials for that topic. However, these teachers might be completely unfamiliar with the topics worked on by other teachers from the same grade. If the school system is very large, there may even be teachers who are unfamiliar with every topic for their grade.

To remedy this situation, it might be profitable to institute workshops in the form of teachers' meetings. For example, the third-grade teachers would meet periodically. At each meeting a group of teachers who had worked on a particular topic would explain the science concepts underlying the topic and demonstrate the experiments and other suggested learning activities selected for the topic. The rest of the teachers could then ask questions, and afterward come up to try the experiments themselves. In this way all the teachers in all the grades would become familiar with the content of the curriculum guide, especially for their own grade level.

The only area that is somewhat rigid in a curriculum guide is the minimum basic science information that has been mutually agreed to be included in the guide. This minimum standard seems to be essential if unnecessary repetition is to be avoided, if the children are to enter the junior high school with any degree of uniformity of science background, and if the junior high school is to be able to plan its own program with any degree of certainty. The remaining areas in the guide should be flexible enough to allow a degree of freedom for the individual schools or teachers. The

various opportunities for flexibility have already been discussed earlier in this chapter, in connection with the desirability of having planned rather than incidental programs.

Also, it is obvious that any curriculum guide should undergo continuous evaluation if it is to be permanent rather than ephemeral. Teachers must be encouraged to analyze critically the contents of the guide as they use it. These criticisms, together with suggestions and recommendations, should be forwarded to the science committee for consideration when the guide is eventually revised.

CHAPTER

4

Methods *of* Teaching Science

METHODS of teaching science make up the third of the three components of an effective science program in the elementary school. Methods—the *how* of teaching science—are the means by which basic science information is learned and objectives are achieved.

Many teachers are concerned almost exclusively with only the methods of teaching science. They feel that this is the really important phase of science teaching and learning. Consequently, when these teachers plan to teach a science topic, invariably their first action is to look for good experiments and demonstrations, which they can perform, or good films or filmstrips, which they can show. They assume that if their selections are good, the desired science learnings and objectives will automatically follow. Often these teachers are very disappointed and frustrated in achieving the

desired results. The teachers then blame the activities they have selected and they therefore discard the activities and continue their quest for better ones.

This procedure is another example of putting the cart before the horse. It is true that the methods of teaching science are the means through which science understandings are learned and the objectives of science are achieved. However, these results cannot be accomplished by selecting the methods first. We must first know what we want to teach and why we want to teach it before we can begin to think of how we want to teach it.

Furthermore, once we know the *what* and *why* of teaching science, the *how* ceases to be a major problem. All that is now necessary is to look for those activities or learning experiences that will best help the children learn the desired understandings and, in the process, achieve the desired science objectives; knowledge of the *what* and the *why* supply purpose and direction in looking for the best methods available. Also, methods selected in this way are much more likely to help the children learn basic science information, know the ways of the scientist, and develop desirable behaviors.

The most common methods of teaching science in the elementary school involve the use of experiments and demonstrations, reading, reporting, discussion, field trips, resource persons, and audio-visual aids.

We should always keep in mind that no single method is superior to any other. Nor should one method be constantly used in preference to others. A variety of methods is desirable when teaching a science topic.

Some methods lend themselves better to a learning situation than do others. Often the availability of supplies and equipment, textbooks and references, or films and filmstrips will help determine the method to be used. Also, the children like variety as well as a change of pace. This variety tends to promote better interest, especially since the children's attention span is not usually long. At the same time a variety of methods will provide different children with an opportunity to assume leadership roles while learning is in progress.

Experiments and Demonstrations

THERE is a definite reason for grouping experiments and demonstrations together. In recent years much has been written about these two teaching techniques. Comparisons have been made, and in most cases the demonstration has suffered. As a result, the demonstration has been either discouraged as a teaching technique or recommended for use only under special circumstances. This is unfortunate because the demonstration has potentialities and values, and it deserves a definite place in the teaching and learning process.

One reason for the decline in popularity of the demonstration may be based upon the connotation given to the terms *demonstration* and *experiment*. The demonstration is usually considered a way of illustrating what is

already known. Thus, after the children have learned the desired science understanding or concept, demonstrations then serve to reinforce this newly acquired knowledge by making it more understandable. On the other hand, the experiment is usually considered a way of learning about or discovering a science understanding or concept for the first time. In this case experiments serve to help the children investigate scientific phenomena, weigh and sift the evidence, and then come to profitable conclusions. In the process the children learn science understandings or concepts and develop desirable behaviors.

The present indictment of the demonstration may have arisen because so many teachers have been using the demonstration in the interpretation described above in preference to the experiment. This use implies a talking-reading type of learning, in which first the children either read or are told about the basic science information and then the teacher does a demonstration to illustrate what they have just discussed or read. At the same time this procedure invokes an unfavorable mental image of the demonstration as being only a teacher demonstration with little or no pupil participation. In either case only the most sterile kind of learning can result.

Actually the demonstration can be used in many ways, all of which should be employed. When properly planned and performed, the demonstration can accomplish almost everything that the experiment can. It can be used to arouse interest and raise questions or problems. It can be used, as already described, to illustrate a science understanding or concept. It can help in solving problems. It can help the children learn how to think by having them apply what they have learned to new situations.

The plea, then, is not to discard the demonstration as a teaching technique, but rather to use it wisely, in the many ways possible.

WAYS OF USING EXPERIMENTS AND DEMONSTRATIONS

Arousing interest and raising questions or problems · Nothing does more to begin a unit or daily lesson successfully than an experiment or demonstration that arouses the interest of the class and raises questions or problems. On a cold, dry day in winter, rub an inflated rubber balloon briskly against a wool suit or with a piece of wool cloth, then place the balloon against the wall. This initiating activity may be done by the teacher as a demonstration or, if enough balloons are available, by the pupils as a class experiment. The children's interest will be aroused immediately when they see the balloon stick to the wall. Their interest should naturally provoke comment and much discussion. When questions are raised and problems stated, the class is well on its way to the study of static electricity.

For most children an experiment or demonstration arouses wonder and delight, especially when the scientific phenomenon involved is one with which the children are unfamiliar. How often the suggestion "Let's do an experiment" immediately brings the class to alert attention. The children's eyes shine and glisten. There is much excitement and interest before, during, and after the experiment. This technique is a very effective means of stimulating pupil participation in learning situations.

When used as an initiating activity for a unit or daily lesson, the experiment or demonstration also serves to give the children an idea of what the unit or lesson is about. It gives them an orientation to the science topic, which is much better than plunging the children directly (and often bewilderingly) into something new and unfamiliar. At the same time, by raising questions or problems, it helps make the children aware that they must learn much more about the science topic before they can explain the experiment or demonstration.

Helping to solve problems · Experiments and demonstrations are ideal techniques for problem solving, which has already been described as one of the key objectives of science in the elementary school. Experiments and demonstrations are helpful in solving such problems as why eyeglasses fog in the winter when a person comes into the warm house from the cold outside, why airplanes fly, how plants get their food, and how heat travels. In the process of solving these problems the children are learning to think critically and to develop a knowledge of the ways in which the scientist operates. The children learn how to define the problem and the terms involved, to make accurate observations and to classify them, to formulate and test hypotheses, to understand the nature of controls and the value of numbers of experiments to ensure reliability and validity, and to draw conclusions.

Applying what has been learned to new situations · In a sense this application serves as an evaluative technique. If the children have really learned the desired science understandings, they should be able to apply what they

Experiments can be used to help solve problems.

Some children can help others do experiments.

have learned to a new situation. Thus, if the children have acquired a thorough knowledge of electromagnets, they should be able to explain the operation of a simple telegraph set. If they are completely familiar with simple machines, they should be able to identify, classify, and explain the operation of many of the common tools and appliances used in the home.

This method of using experiments and demonstrations helps, at the same time, to relate what has been learned to the children's environment. Furthermore, the method is directed toward developing critical thinking, because the children must now review closely the aspects of the experiment or demonstration, weigh and sift the evidence, call upon their store of basic science information, make and suspend judgments, hypothesize, and finally come to a satisfactory conclusion.

Encouraging and challenging slow and rapid learners · The performance of experiments and demonstrations provides an excellent opportunity to help the slow learner. They help develop the ability to observe and report accurately. They help give the slow learner needed confidence in organizing data, in sensing problems, and in solving these problems scientifically. They provide the satisfying status involved in occasionally assisting the teacher and in having the opportunity to explain to the rest of the children the reasons or principles underlying the experiment or demonstration.

Experiments and demonstrations are also an excellent way to challenge the rapid learner. There are several ways in which this challenge can be accomplished. The rapid learner can repeat demonstrations done by the

teacher to gain new insights. He can do additional experiments by himself with the consent and supervision of the teacher. He can assist the teacher in doing demonstrations or experiments. In this situation the teacher should make sure that the rapid learner is a real assistant, and not a helper who fetches and carries materials and who then cleans up and stores the materials afterward.

The rapid learner can also be of great value in helping the slow learner. In many cases a child can explain or demonstrate things very satisfactorily to another child, even after the teacher has failed to do so. It often seems as if the children have their own special jargon, by which they communicate with each other very effectively. Besides, while helping the slow learner, the rapid learner is also helping himself. In the process of helping the slow learner, the science understandings involved in the experiment or demonstration become quite firmly fixed in the mind of the rapid learner. It is a common axiom that a person really knows a subject when he is able to explain it effectively to another person.

SUGGESTIONS FOR DOING EXPERIMENTS AND DEMONSTRATIONS

The experiment or demonstration should have a purpose · Do not perform experiments and demonstrations without a specific purpose. Some teachers may think that, as long as they conduct a large number of experiments and demonstrations in class, they are teaching much science and at the same time gaining a reputation as good science teachers. This impression is completely erroneous. Every experiment or demonstration should have a definite purpose, either as a planned, integral part of a daily lesson or as a learning situation that has arisen extemporaneously.

Moreover, this purpose should be altogether clear, so that it is known and understood by all the children. In every experiment or demonstration the children should know just what they are looking for. Otherwise the results may be ineffective and meaningless.

Planning is important · Experiments and demonstrations should be planned carefully and exactly. The necessary materials should be collected in advance and be ready for assembling or distributing so that there will be no delay or break in continuity of the learning situation. Also, the experiment or demonstration should be tried out in advance, regardless of whether it is a simple or complicated procedure and whether the teacher is inexperienced or experienced. Nothing is as embarrassing as an experiment that does not work in class. Even though the instructions in the text or reference book are usually clear, sometimes there are slight ambiguities or tricky manipulations. By doing the experiment or demonstration in advance, the teacher can clear up these complications and revise or amplify the instructions so that successful performance will be assured.

It is also a good idea to follow instructions very carefully and exactly. Very often a person is tempted to heat a solution a little longer or add more

than the called-for quantity of a chemical to make sure the demonstration or experiment will go well. In such cases sometimes the result is likely to be quite unexpected, ineffective, or even disastrous.

Find opportunities to involve the children · The children can help in defining the purpose of the experiment or demonstration. Children can often state the purpose in a much more challenging way than the teacher. When this kind of statement is made, the experiment or demonstration now becomes much more meaningful to the children. In a sense it has become their personal property and problem.

The children can help in planning experiments and demonstrations. This involves many worthwhile phases and methods of learning. For example, they may read and discuss the science principles involved. They may suggest different ways and means of doing the experiment or demonstration. They may plan and work together. They may collect materials. They may gather and organize observations and data. They may plan to check their findings and conclusions. In this way it becomes their plan. And if something should go wrong with the experiment or demonstration, they now have a personal stake in finding out why it did not work.

Whenever possible, let the children do the experiment or demonstration themselves. If this procedure is not advisable, one or more children can assist the teacher. This privilege should be rotated so that all the children will have an opportunity to participate. In those cases where, for various reasons, the experiment or demonstration is performed by just one or two persons, the teacher should always keep in mind that it is being given for the benefit of all the children. The teacher should check to make sure that the experiment or demonstration is performed in such a way that it is interesting, clearly presented, serious rather than laugh provoking, not too long or tediously performed, and capable of producing the desired outcomes.

Finally, the teacher should keep in mind that the children themselves can originate experiments and demonstrations. Very often an experiment or demonstration will raise further quesitons and problems that suggest or call for original investigation. The teacher should take advantage of the situation because it involves the children in all the elements of the problem-solving process. It also has the added advantage of offering a challenge to the children, especially the gifted.

Aim for thinking and discussion · Wherever possible, conduct the experiments and demonstrations in such a way as to arouse thinking and discussion. Do not tell the children the answer or have them read the answer in advance because, if you do, there is often no point in doing the experiment or demonstration. When the children are told in advance that the experiment they are to do will show them that the shorter the vibrating string the higher the musical note produced, this advance information will immediately take away the thrill of discovery and will destroy much of the interest.

Simple and easily visible experiments are desirable.

Open-ended experiments lend themselves very well to thinking and discussion because children cannot anticipate the results before they do the experiment. Open-ended experiments excite the children's curiosity and stimulate their imagination. They respond instantly to the challenge of the question, "What will happen if . . . ." Through thinking and discussion they can devise ways and means of attacking the problem, suggest experiments or other ways and means of solving the problem, even devise equipment at times, make careful observations and notations, and check their conclusions to see if they are correct. As stated before, one of the bonuses of open-ended experiments is that the experiments often raise new problems, which require more open-ended experiments, and consequently more learning takes place.

Keep the experiments and demonstrations simple and easily visible · Use simple and familiar materials rather than complicated and specialized equipment. Although some of the simple apparatus used in the high schools may be most helpful and even necessary, there is no justification for a wholesale transfer of high school equipment and apparatus to the elementary school. Complicated and unfamiliar equipment will often distract the children's attention. They become much more interested in the way the equipment works rather than in the results of the experiment or demonstration. In many cases the simpler and more familiar the materials, the more effective the experiment or demonstration.

The experiment or demonstration should be easily visible to all students.

This is an aspect that many teachers forget or ignore. There is no reason to assume that, because the equipment is easily visible to the children in the front of the room, all the other children can see it just as well. Furthermore, there seems to be a common tendency to keep the demonstration table so cluttered that the children either cannot see what is going on, or their attention is distracted by the other materials on the table. When one or two persons are doing the experiment or demonstration, they should be in back of the counter or table. The table should be high enough so that all can see quite clearly. The lighting should be checked so that visibility is good for all. Use equipment and materials that are as large as possible. As it is they will look small enough to those children in the rear of the room. In some cases it may be helpful to have the experiment or demonstration done in the middle of the room so that all the children can gather around to watch it.

Apply what is learned to the children's environment · Experiments and demonstrations should do more than answer the immediate questions and problems. If there is to be any real value gained, the experiment or demonstration should also help answer questions about things that are happening in the children's daily environment. The results should be applied to corresponding situations that occur in everyday living. Thus, the children should learn not only that dark objects absorb more heat than do light objects, but also that for this reason light-colored clothing is preferable in the summer and dark-colored clothing is preferable in the winter.

Repeat the experiment if necessary · Sometimes the understandings or concepts involved in an experiment or demonstration are quite complex or numerous, so that it is necessary to repeat the experiment if the learning is to be profitable to all the children. Teachers and children, when doing a demonstration, often run through it quickly without giving the rest of the class an opportunity to grasp all the understandings and implications involved. They forget that what seem like simple ideas or relationships to them may be unfamiliar to the other children. Whenever this problem occurs it is advisable to repeat the demonstration.

Use controls and numbers of experiments wherever possible · The use of controls in experiments and demonstrations is one of the tools of the scientist. Children are able to understand very easily the need for, as well as the nature of, a control experiment. In an experiment using a control, all the conditions of the experiment are duplicated except one, and this single condition is the one that is being tested. For example, when studying the effect of heat upon the rate of evaporation, a control helps prove conclusively that heat makes liquids evaporate more quickly. The same measured quantity of water is poured into each of two identical pie tins. One tin is placed on the hot radiator, and the other tin is placed on a table

Aim for quantitative as well as qualitative results.

on the other side of the room. The windows and door are kept closed so that any effect caused by the wind or air circulation will be eliminated. Now all the conditions are the same except one, namely, the temperature to which the water is exposed. Consequently, as a result of the control, the results of the experiment become clear-cut and obvious.

Teaching the nature of a control experiment to children today is much less complicated because the children have been exposed to television. The commercials widely use so-called "experiments" with controls to prove a product superior. It would be an interesting assignment for the children to observe closely to see if all the conditions but one are duplicated, and especially to look for unwarranted assumptions. This observation would create a learning situation that would be just as popular and profitable as the situation involving superstition versus science.

After the children have learned the nature and value of control, they should also be exposed to the necessity of sometimes having to use numbers of experiments to secure results that are valid or reliable. Children are quick to understand the need for using numbers of experiments. If a teacher were to suggest that the class should conduct an experiment to see which was the faster writer, a right-handed or left-handed child, the class would be quick to object to an experiment involving just one right-handed and one left-handed child. The need for using a number of children to make the experiment reliable would be obvious to all.

Similarly, when you are trying to show that in growing plants the roots tend to grow downward and the stems upward, it is apparent that a

number of growing plants must be used. When you are finding the dew point (the temperature at which water vapor in the air will condense back into water), it will be so difficult to note the exact temperature when the dew point is reached that the children will recognize the need to repeat the experiment a number of times and perhaps take an average to obtain satisfactory results. In these ways experiments requiring a number of repetitions will help prevent the children from making broad generalizations on the basis of just one experiment.

Aim for quantitative as well as qualitative results · Science in the elementary school has been primarily qualitative in nature; very little has been quantitative. Quantitative results should also be stressed. The children are constantly exposed to the "why" and "what" of science and rarely to the "how much." As a result a golden opportunity is being missed not only to show the child key relationships, but also to tie in the science program with the arithmetic program.

Take, for example, the experiments designed to show how the strength of an electromagnet may be increased. It is customary to prove this either by increasing the number of turns of wire around the piece of iron or by using more dry cells.

However, consider how much more effective a learning situation this becomes if we make the experiments quantitative in nature. When first making the electromagnet, the children wrap 30 turns of wire around the iron nail or bolt. Then they count the number of tacks the electromagnet will pick up. Now when the children wrap 60 turns of wire around the iron nail, they find that the second electromagnet will pick up twice as many tacks. There should be little difficulty in realizing that, if we double the number of turns of wire, we double the number of tacks that will be picked up. Consequently, the electromagnet has been made twice as strong. If the experiment is repeated, however, this time using the same number of turns of wire in each case and using first one and then two dry cells (connected in series), the results will be the same as when the number of turns of wire was doubled. If we double the number of dry cells, using the same number of turns, we double the number of tacks that will be picked up, and again we have made the electromagnet twice as strong. The children could then be asked to find out what would happen if we doubled both the number of dry cells and the number of turns at the same time.

In this experiment the children not only learn science understandings and principles, but also are given an opportunity to discover mathematical ratios and relationships (not to mention practice in counting). There are many opportunities in the teaching of science to include the teaching of numbers, size, and simple ratio. This is a phase that has been neglected too long.

Aim for quality not quantity · Because the elementary school curriculum is already so crowded and because such a small portion of the school day

is usually devoted to teaching science, minutes become very precious. At the same time the teacher will often come upon several different demonstrations or experiments, all of which illustrate or develop the same science understandings or principles. Because all these demonstrations and experiments are quite effective or even spectacular, the teacher is often tempted to use all of them. The teacher may justify her decision by believing that the repetition will help secure the children's learning of the understandings involved. Although this justification may be true in some cases, it is likely that a teacher who follows this practice repeatedly will teach much less science than actually should and could have been taught during the school year. The primary loss, of course, will be to the children.

The teacher, then, should look for quality when selecting experiments and demonstrations, restricting herself to experiments and demonstrations that will teach the most and best in the shortest possible time. The emphasis of quality over quantity will vary somewhat in the lower and upper elementary grades. In the lower elementary grades the amount of basic science information to be taught is still relatively small, and the ability of the children to read and to think abstractly is low. Consequently, it would seem advisable to use a comparatively large number of experiments and demonstrations to ensure proper learning of the basic science information. In the upper elementary grades, however, the amount of basic science information to be taught becomes progressively larger. Time is important, and quality of selection becomes increasingly more important than quantity.

It should be noted that this suggestion is not intended to minimize the use or value of doing experiments and demonstrations. It is meant as a recommendation not to use them exceedingly. If the teacher has collected many experiments and demonstrations and then decides not to use them all, the excess need not be wasted. They should be set aside for both slow and rapid learners. When time is available the slow learners can do some of these experiments and demonstrations to reinforce their knowledge of the science understandings involved while the rapid learners can do the others to extend their knowledge further.

WHEN EXPERIMENTS AND DEMONSTRATIONS FAIL TO WORK

Sometimes experiments and demonstrations fail to work. This can happen even if the teacher and children have followed the instructions carefully and accurately, measured out the exact amounts, checked the apparatus and equipment, and even tried out the experiment or demonstration in advance. Many teachers are embarrassed when this happens, especially new and inexperienced teachers. They may become distressed because what they have worked so hard to accomplish seems to have fizzled miserably. They may even feel that they have lost face or prestige, and as a result appear inept or incompetent before the children. If it happens often, these teachers may become reluctant to use experiments and demonstrations in class, or perhaps even to teach science.

The greatest embarrassment often occurs when the teacher has planned and executed the demonstration or experiment without involving the children. What happens then is that the teacher immediately begins to look for the source of the failure. The children, who constitute an inactive audience, will watch interestedly at first, and some may even offer suggestions. If the teacher unwisely tells the children to be quiet, the children will then lose interest and soon become restless and often noisy. The teacher, who is already frustrated because the source of the failure cannot be located, becomes annoyed with the children and speaks sharply to them. Thus, the harmony of the classroom is broken, the learning situation is a complete loss, and both the children and teacher are disturbed and upset.

Actually, the teacher has failed to take advantage of a valuable learning situation. When an experiment or demonstration does not work, the failure becomes a real problem for both teacher and children; the children have been given an unexpected opportunity to help solve a common problem, to think critically, and to offer solutions. If the children have been involved in the experiment or demonstration from the beginning, they will have a vested interest in the outcome and any difficulties that may arise.

When an experiment or demonstration fails to work, then, first analyze the situation, with the help of the children, and decide upon the possible reasons for the failure. Next, check each factor methodically and carefully. It is likely that the cause of the failure will become apparent, and a valuable learning experience will have been gained.

One elementary school teacher took advantage of the failure of a demonstration when the class was studying expansion and contraction. To prove that gases expand when heated, a demonstration was selected involving a rubber balloon and a soda bottle. The balloon was snapped over the neck of the bottle and the bottle was placed upon the radiator in the room. Ordinarily the balloon will fill up and grow larger as the air inside the bottle is heated and expands. This time nothing happened. The teacher was disconcerted because the same demonstration had been used in other classes, always with successful results. However, the teacher immediately called upon the class for suggestions because, the children had helped select the demonstration. After some discussion the children concluded that either the balloon was punctured, the bottle was cracked, or the radiator was not hot. Each reason was checked, and the cause of the failure, a radiator that had cooled down, was quickly found. Instead of being annoyed or frustrated, both the teacher and the children were quite pleased that they had solved this problem so quickly and scientifically. Even more rewarding to the teacher was the realization that a routine demonstration had become a real source of experiment and investigation.

It is important to remember that if every possible reason has been suggested and tried and the experiment or demonstration still does not work, the fault may lie with the reference or textbook from which the instructions were obtained. Some books may suggest experiments and demonstrations that the authors have not tried themselves. In other cases ambiguous or

incomplete directions are given, or the authors have failed to warn the reader of an especially tricky manipulation. Because more than one textbook will usually contain the experiment, it might be wise for the teacher to check a second source.

A final suggestion is that the teacher not spend too much time on an unsuccessful experiment or demonstration. If, after every suggestion that has been offered has been tried and the cause of the failure still cannot be found, further investigation will only be a waste of time. Ask the children to think about it overnight and come in the next day with further recommendations. Meanwhile try to get in touch with an experienced science person, such as a junior or senior high school science teacher or a scientist, as soon as possible for suggestions and advice.

TEACHER OR PUPIL EXPERIMENT AND DEMONSTRATION?

The elementary school teacher is consistently urged to involve the children when doing the experiments and demonstrations. The teacher is reminded constantly that science is a *doing* subject and that the children rather than the teacher should do the doing. This suggestion is obviously intended to discourage the teacher from dominating the lesson by doing all the experiments and demonstrations while the children become a passive audience. However, often the teacher is likely to go too far in the opposite direction. In an effort to use what is considered good teaching practice, the teacher may completely withdraw and encourage the children to do all the experiments and demonstrations. This practice can be equally undesirable, and even impractical.

There is no fixed rule about who shall do experiments and demonstrations. Sometimes the teacher should do them and other times the children should do them. In some cases it is advisable for the teacher, or one or two children, to do an experiment rather than the entire class. In some cases the teacher alone should do the demonstration whereas in other cases the children should do it with the teacher acting as an assistant. There are several factors that should be considered whenever a teacher is trying to decide whether the teacher or children should do an experiment or demonstration.

Safety · The safety factor is extremely important when deciding who shall do the experiment or demonstration. The use of strong acids or bases, heat or flame, or any other procedure involving a hazard—especially in the lower elementary grades—should automatically make it advisable for the teacher to do the experiment or demonstration. Accidents in the classroom almost always produce awkward situations and should be avoided wherever possible.

Sufficient equipment · Sometimes the availability of the equipment will easily solve the problem about who should do the experiment. If there is very little available equipment and no hazard, the logical decision would

be for one or two children to do the experiment. If there is sufficient equipment, all the children should participate.

Expensive apparatus · If the apparatus is quite expensive, it is likely that there is only one of its kind available. This fact would immediately limit the performance of the experiment or demonstration to the teacher alone with the assistance of one or two children. If the teacher is willing to take the risk, however, the experiment or demonstration may be conducted by one or two children with the teacher close by to assist or watch.

Time · Time is also an important factor because such a small portion of the daily program is usually allotted for teaching science. The beginning teacher sometimes does not realize how much time may be involved when the entire class is doing an experiment. Materials must be distributed; instructions must be given (and repeated); time must be used to see that everyone is doing the experiment properly; then the materials must be collected. There is not enough time available in the school day for all the children to do every experiment. The teacher, therefore, should constantly evaluate each experiment. If the value to be derived by having all the children participate is worth the time, by all means have all the children do the experiment.

Another factor involving time is the procedure for doing the experiment. If the procedure is complicated or tricky and requires an unusual amount of time and effort to explain it to the class, it might be better to have the experiment done by one or two children, or just the teacher.

Learning potential · Perhaps the most important factor in trying to decide who shall do the experiment is the amount or kind of learning that will take place in each case. If the class would learn just as much when one or two children do the experiment, time is important enough to warrant one or two children doing the experiment. Take, for example, the experiment to find out the law of magnets, that is, when like poles repel and unlike poles attract each other. The children would learn little more, if any, by doing the experiment themselves rather than by watching one or two of their classmates do it. There are no further understandings to be learned, or new abilities or skills to be gained, by having all the children do the experiment.

However, when studying open and closed electrical circuits or good and poor conductors of electricity, there are definite values to be gained by learning how to set up a simple electrical circuit. In this case, greater insights may be attained, and abilities and skills may be acquired, which would warrant having each child do the experiment.

Thus, if there is no difference in the amount and kind of learning that will take place, have one or two children perform the experiment rather than the entire class. But if there is a difference, and especially if abilities and skills are also involved, let the entire class do the experiment.

Reading is an integral part of science learning.

Reading

LEARNING science through reading is and will continue to be one of the most important methods of teaching science in the elementary school. Not everything can be learned either directly by doing experiments and demonstrations or vicariously by taking field trips, bringing in resource persons, and using audio-visual aids. There is much that can, and must, be learned by reading the material contained in textbooks, supplementary books, magazines, bulletins or journals, and newspapers.

The ability to learn through reading is a reliable indication that, by being able to absorb abstract ideas successfully, the children are growing in mental maturity. The use of reading in science can also make a valuable contribution to the reading program in the elementary school. It can help develop the children's vocabulary, increase their enjoyment in reading, and stimulate their desire to read for information.

The use of reading as a method of teaching science has occasionally been criticized. This criticism has not been directed at the use of reading as a means of learning, but rather at its misuse. Too often the learning of science in the elementary school has been nothing more than reading about science. When this type of teaching occurs, the learning of science becomes quite sterile and unproductive, with the consequent loss of interest by the children. Little, if any, real and lasting values result. When properly handled, however, reading can make a vital contribution to learning.

Reading is most effective when it has a purpose. Nothing can make the

children dislike or lose interest in science more quickly than an arbitrary reading assignment, followed by talking or discussion. On the other hand, when reading has a purpose, interest is easily aroused and enthusiasm is kindled.

Reading for a purpose can be used to motivate the study of science in all phases of the learning process. It can be used in planning or preparing for experiments, demonstrations, field trips, resource persons, films, and filmstrips. While these activities are going on, reading can be used to find answers to questions, solve problems, and obtain additional information. When finishing these activities, reading can be used to check findings and conclusions. It can also reinforce, supplement, and extend further what the children have learned.

SUGGESTIONS FOR USING READING

Aim for helping the children to think and learn · Reading can be used to encourage the children to think. After the children have read with a specific purpose in mind, reading should be followed by discussion, experiments, reports, or any other activities that will help the children express and interpret what they have read and learned. Also, keep in mind that one of the ultimate goals of reading is to help the children acquire concepts that they can use now and in the future.

Teach the children how to use reading materials effectively · As the children become sufficiently mature, teach them how to use the table of contents, index, and glossary. Give the children practice in how to find the information they are seeking. It would be helpful to familiarize them with the broad science areas and topics under which the more specific terms would be listed.

Make sure the children are aware of the different sources—supplementary books, encyclopedias, bulletins, journals, magazines, newspapers, and so forth—where they may obtain the information they want. Show them where all these materials are located in the library. If there is a card catalog, help the children learn how to use it.

Simple charts may be new to the children. Discuss one or two such charts in class and show the children how to read them. The same is true of line drawings and diagrams. The children should also learn how to take notes about what they are reading, especially if they are preparing reports.

Point out the difference in purpose of the various reading materials · Some books are written primarily for the reader's enjoyment. Although attention may be paid to detail and accuracy, the prime purpose of the book is to give pleasure. Animals and plants may speak or are given human characteristics. Other books are written primarily for reference and information. Although both kinds of books are acceptable, the children should learn to make a distinction between them and use each kind for the purpose it was intended.

Have several sources of information available, on different reading levels · Although most textbooks and supplementary books contain approximately the same science information, they do vary both in style and content. Some present the material from a slightly different or simpler point of view. Some may be a little more complete or may have clearer and more detailed drawings and diagrams. Some may have more experiments and "things to do" in them. All of them, when made available to the children, supplement each other and help provide a rich background of material that the children can explore and utilize.

Because the reading ability of the children will vary in each class, it is wise to have reading materials on different levels. Most elementary textbook series do not agree on the grade placement of science topics. Consequently, it is not unusual to find a science topic in a fifth-grade textbook of one series, and in fourth- or even sixth-grade textbooks of other series. Thus, even if the class is committed to one textbook, it will be helpful to have a few copies from other series available.

Supplementary textbooks, which have been written on many science topics, range in content and readability from lower elementary grade levels to junior or even senior high levels. If the teacher has a variety of such references available, she will provide reading materials suitable and appropriate for children of all levels of reading and learning ability.

Several weekly and monthly magazines often present material that is not only scientifically accurate but is written from a human interest point of view. These sources also contain beautifully colored illustrations, which ordinarily do not appear in textbooks and reference books. Children like these magazines and find them highly informative and useful.

Aim for developing the children's science vocabulary · The science program is just one part of the elementary school curriculum. It should never be considered or treated as different and apart from the rest of the learning that goes on all day in the classroom. It should be correlated, when possible, with the language arts, social studies, arithmetic, and other programs in the elementary school. It follows, then, that reading from a science book is no different from reading from any other book for developing vocabulary. Here the emphasis is on learning science words.

When new words appear while the children are learning science, the exact meaning of these words should be made evident to the children. Close attention should be paid to the correct spelling of such words. Give the children an opportunity to say the words out loud a few times to get the feel of the word on their tongues. Children are often delighted with the way a word sounds when spoken aloud. Take advantage of this delight to fix the word clearly in the children's minds.

Develop the understanding of science words through experiments, discussion, reports, and other activities. Encourage the children to use these words freely during their learning experiences. Look for opportunities to use the words later, when the children are learning about other science

topics that are related to the topic where the words were originally introduced.

Reports

THE USE of oral and written reports in teaching science is fairly common in the elementary school. When properly presented, both oral and written reports will provide a valuable learning experience for the children giving the reports as well as for those children listening to the reports.

Very often, however, the children's reports can be disappointing to the teacher. The results are not those for which the teacher hoped or expected. When giving oral reports, for example, sometimes the children are either incoherent or speak so softly that they cannot be heard. Some oral reports seem to have no logical method of presentation, and they wander aimlessly. Some reports are long and drawn-out whereas others are absurdly brief. Many reports are not true oral reports, but rather written reports read orally. The result is that oral reports are often boring, confusing, or even mirth provoking.

Written reports also suffer from the same shortcomings. There is also an additional hazard. Too often the contents of written reports have been copied literally from textbooks, supplementary books, and encyclopedias. Interestingly enough, the children as a rule are surprised that the teacher is able to spot a "copy job" so quickly. They apparently do not realize that the writing style in textbooks and supplementary books, and especially in encyclopedias, is unique, designed to give the maximum information in the shortest possible space, and consequently it is not too difficult to recognize.

A few children acquire ease with oral and written reports quickly, but most children do not. Yet all the children should learn how to present oral and written reports, especially in science, because reporting science information requires great clarity.

The elementary school teacher should teach the children how to report properly. The time used for this purpose will produce results that are well worth the effort. Point out that each report, oral or written, should have a beginning, a middle, and an end. The beginning of the report contains the title or purpose of the report, often stated to catch the listener's or reader's interest. The middle of the report contains the body of information to be communicated. The end of the report contains the summary and conclusions.

When oral reports are given, they should be quite short, lasting no more than about five minutes. They should be clear and explicit, and stated in the children's own words. The children may refer to notes, but there should be no wholesale reading from the notes. The children should be instructed to speak loudly and clearly. The children should put diagrams and new vocabulary words on the chalkboard in advance so that the continuity of the report will not be broken and the comprehension of the audience will

Discussion is a valuable adjunct to learning science.

be maintained at all times. Oral reports have greater value when afterward the class is requested to ask questions and discuss the report.

The content of the written reports should be simple and clear, and in the children's own words. Point out the evils of plagiarizing and teach the children the use of quotes, when this becomes necessary. Encourage the children to express their own opinions and to reach their own deductions and conclusions. Help them learn how to give the sources from which they obtained their information for the report.

During the school year every child should have an opportunity to present a report. In this way they will acquire practice and skill in one of the techniques of communication that the scientist so often uses.

Discussion

Discussion as a method of teaching science is not usually treated separately in most science methods texts for the elementary school because, as a teaching technique, it is rarely used alone but rather in conjunction with all the other methods. However, since it is so closely associated with every other method of teaching science, it deserves consideration at this time.

The uses and values of discussion are manifold. It is an excellent means of communication between teacher and children. Through discussion the

teacher learns to know the children, and the children develop a closer bond with the teacher. Discussion can be extremely valuable in initiating a unit. When planning to involve the children in a unit, the teacher first begins with a thought-provoking experiment, demonstration, or question. Or the teacher may even begin with an eye-catching display, either of actual models and specimens, or of pictures and drawings on the bulletin board. These techniques invariably arouse interest. Questions or problems are raised, which are followed by much discussion as the children and teacher plan together to answer the questions or solve the problems. When this process occurs, the unit is being directed toward successful participation and completion.

While the unit is in progress, discussion helps in explaining or clarifying experiments, demonstrations, reading, reports, field trips, resource persons, films, filmstrips, and television programs. When solving problems discussion is one of the techniques that can be used to define the problem, suggest methods of solving the problem, and check results and conclusions. Discussion can also help the children learn how to think critically, as they become involved in the process of developing science understandings and concepts, making interpretations and judgments, and trying to apply what they have learned either to their environment or to new situations. At the same time discussion tends to develop desirable scientific attitudes and behaviors, such as respecting the opinions of others, rejecting unreliable or unqualified evidence, not jumping to hasty conclusions, listening intelligently, speaking effectively, and participating cooperatively and democratically.

Discussion can also serve as an evaluation technique. It can be used as a pretest to find out how much the children already know about the science topic to be studied. The teacher can determine through discussion if the children have learned the basic science information or acquired scientific attitudes and desirable behaviors. It also enables the teacher to find out which children are extroverts and which children are shy or withdrawn, and therefore have to be encouraged and drawn out of their shells. It helps the teacher to identify the slow and rapid learners.

When holding a discussion the teacher should remember certain things. First, the function of the teacher during a discussion is to be a combination guide, helper, leader, and director of learning. To keep a discussion going profitably, the teacher must curb the impulse to interrupt constantly. Otherwise the children will tend to turn constantly to the teacher as the person who makes the final decision. The teacher, of course, should interrupt when the discussion seems to be going off on a tangent or in the wrong direction. When the children begin to flounder, the teacher can then offer suggestions. However, the teacher should restrain herself from giving answers; rather, she should try to answer a question with another question that will point the way to the answer. Also, during the discussion the teacher should make sure that every child who so desires will have an opportunity to participate in the discussion. Otherwise a few children may monopolize the discussion and thus exclude shy or quiet children who may have much to offer.

Second, there is a strong temptation for the teacher, who already knows the answers, to insist upon a quick, rapid-fire discussion. This procedure is unwise because discussion can be something new to many children. They need time to recall previously learned science information, to digest new ideas, to apply the information or ideas to new situations, and to arrive at or propose solutions. By insisting that the children take enough time to formulate and express their thoughts clearly, the teacher will help discourage quick, superficial, and inaccurate thinking.

Third, the teacher should make a point of not showing undue amusement at the children's statements or responses. If a suggestion is offered that is unintentionally absurd and the teacher sets the pace for the rest of the class by bursting into laughter, the resulting embarrassment and humiliation to the child will tend to discourage any further participation in the discussion. If the class begins to laugh, the teacher should attempt to stop it as quickly as possible, either by asking the class to calm down or by calmly explaining why the suggestion is not feasible. When a child is intentionally absurd, however, this behavior is a breach of discipline, and the child should be told firmly to act as a responsible member of the class. Another thing the teacher should guard against during a discussion is the tendency to ask a child a question and then press insistently for a response when the child obviously does not know the answer. This demand can only result in withdrawal, antagonism, and even tears. It is much better to pass over the child and keep the discussion going smoothly by calling on another child.

Finally, it is important to remember that discussion works best when the children have previous learning or experiences upon which to draw or call. This fact explains why discussion is usually used in conjunction with the other teaching techniques. While the unit is in progress, a discussion presents no problems because a sufficient number of activities have been carried out to provide the children with the necessary background or experience to participate freely in the discussion. However, to begin a unit with discussion alone is another matter. If the children have had no previous background or experience in the science topic, the discussion often becomes a teacher monologue or lecture, in which the teacher both asks and answers the questions. To ensure adequate discussion when initiating the unit, more-experienced teachers first begin with an interesting or thought-provoking experiment, demonstration, question related to the children's environment, or display. This procedure ensures a discussion in which the children can make intelligent and constructive contributions to the questions and problems raised by the original initiating activity.

Field Trips

FOR MANY teachers and school systems the term *field trip* is interpreted as a visit by the teacher and children to museums, aquariums, planetariums, or industrial plants within the community. Actually, the term has a broader

and more inclusive meaning. The field trip should refer to any learning activity that is carried on by the children as a group outside the classroom. Other terms are used for this kind of learning activity, depending upon the various school systems and their locality. The most common alternate terms are *excursion* and *school journey*.

The field trip is a unique teaching technique in that, like experiments and demonstrations, it provides the children firsthand experiences with materials and phenomena. It goes further than experiments and demonstrations, however, by providing experiences that cannot usually be brought into the classroom. Often it enables the children to see the materials and phenomena in their true or natural relationships. It helps the children see more clearly how the basic science information they have learned applies to their environment. When visiting major industries in their community, museums containing indigenous materials, or geographical points of interest, the children can begin to understand and appreciate the contributions of their community to the state, area, or country. The field trip has the added advantage of being an activity that lends itself very easily to integration with the other phases of the elementary school curriculum. As a result, the other areas of learning can benefit whenever a field trip in science is taken.

WHERE TO VISIT

All communities, urban or rural, offer a wide variety of opportunities for the children to take field trips. These may vary in time or distance. A great many can take place in or close by the school. In the school building itself the children can, for example, visit the furnace and learn about fuels, heat, and how heat travels. In the school yard the children can explore plant and insect life, the teeter-totter (as a lever), the flagpole (as a pulley), weather and different forms of precipitation, soil, and erosion. Within walking distance of the school there may be industrial plants, quarries, dairies, or other establishments. Many of these field trips will take comparatively little time and can be used to supplement rather than interfere with activities planned for other phases of the elementary school curriculum. These field trips are just as valuable and instructive as the occasional longer trips taken to museums, zoos, factories, and other places of interest.

To utilize fully the potentialities of the community for field trips, it is wise to make a survey of all possible sources for field trips. This survey should include not only the immediate vicinity but the surrounding areas as well. The preparation of a file of potential field trips can be most helpful to the teacher. Each card can include the place to be visited, where it is located, what it has to offer, and other pertinent information. In many school systems, groups of teachers have compiled comprehensive lists of places to visit. These lists have been put into booklet form and then distributed to all the teachers in the district.

The following are some of the places that can be visited in cities, towns, or rural areas with profitable results for the learning of science.

1. Airports.
2. Apiaries.
3. Aquariums.
4. Automobile service stations.
5. Backyards.
6. Bird sanctuaries.
7. Botanical gardens.
8. Buildings under construction.
9. Chemical plants.
10. Dairies.
11. Farms.
12. Fire departments.
13. Flower shows.
14. Forests and forest preserves.
15. Gardens.
16. Gas companies.
17. Gravel pits.
18. Greenhouses.
19. Health departments.
20. Industrial plants.
21. Mines.
22. Museums.
23. Newspaper plants.
24. Observatories.
25. Orchards.
26. Parks.
27. Photography establishments.
28. Planetariums.
29. Power plants.
30. Quarries.
31. Radio stations.
32. Sanitation departments.
33. Sawmills.
34. Scientific apparatus companies.
35. Shorelines (lake and ocean).
36. Telephone buildings.
37. Television stations.
38. Water purification plants.
39. Weather bureaus.
40. Zoological parks.

WAYS OF USING FIELD TRIPS

Introducing a unit · This method is particularly effective when the children have had little or no background in the science topic to be studied. The field trip then serves as a motivating factor to create specific interest in the science topic. In this way the children are able to get an overview of the topic and a desire to learn more about it. The teacher should keep in mind that, when using a field trip to initiate a unit, the main purpose is to arouse interest and raise questions or problems and not to find answers.

Obtaining information during the unit · Probably the best time to take a field trip is while the class is obtaining information during the unit. In the middle of the unit sufficient questions or problems have been raised that would warrant taking a field trip. In this case the children can use the field trip to find the answers to their questions and problems, and also to check on previous experiments, reading, discussion, and conclusions. At the same time the field trip may raise further questions and problems, and thus lead into the next phase of the unit.

Providing a culminating activity · When used as a culminating activity at the end of the unit, the field trip is an excellent technique for summarizing the highlights or important understandings of the science topic that the children have studied. This activity helps fix the learnings firmly in the children's minds. The field trip also gives the children an opportunity to really see many of the things they have read or talked about. When planning the field trip as a culminating activity, care should be taken not to try

Field trips are excellent culminating activities.

to recapitulate all the learnings in the entire unit. This procedure will tend to make the field trip tedious and boring. Try instead to select the key understandings to be reviewed, and then use the field trip to illustrate and consolidate these understandings for the children.

SUGGESTIONS FOR TAKING FIELD TRIPS

The field trip should have a purpose · The field trip can be effective as a teaching technique only when it has a purpose. There must be a real reason for taking the field trip. The purpose may be to introduce or arouse interest in a new science unit, to find the answers to questions and problems raised during the unit, or to summarize the highlights and important understandings of the unit. Whatever the purpose, it should be understood by all the children. If there are special things to look for or if answers to questions or problems are to be found, make sure the children have these items clearly in mind.

Do some preliminary investigation and planning · Before the children take the field trip some necessary investigation and planning must be done. Exactly what does the field trip offer? Is it suitable for the grade level and ability of the children? If the visit is to certain establishments such as museums, industrial plants, public service departments, and so forth, how many children will be allowed to come at one time? What hours are these

places open? Is there a fee involved? If there is a fee, will it be paid by the children or by the school?

Find out when would be the best time to take the field trip. Some establishments like to have sufficient notice, especially if visits to these places are quite popular. Others may prefer that the children come only in the morning or afternoon. Inquire if there is a guide or suitable personnel member available so that this person's services may be reserved.

Check to see if there are special arrangements to be made with the school authorities. Some school systems limit the number of full-day field trips that a teacher may make each year. This limitation requires that the best possible selection be made for the field trips in science. Do the children have to obtain written permission from their parents, especially if transportation is involved? Are there any interested parents who might like to join the trip as assistants or guides?

An important phase of preparing for a field trip is inquiring about and planning for transportation. Does the school provide a bus? Is there a fee involved? If there is a fee, is it paid by the children or the school? If the school does not supply transportation, find out what other kinds of transportation are available. Does the school have group accident insurance for the children when they take field trips by school bus or private transportation? Some localities allow children to travel in private cars. If so, arrangements must be made for all the cars to meet at a certain place at an agreed time. The route to be taken should be worked out and well known to all the drivers. Give specific, and perhaps written, instructions about meeting places, starting time, route, and time of return. Have a driver who knows the way lead the procession. Find out about parking facilities. Also, check if the children are covered by the owner's accident insurance when riding in private cars.

Make a preliminary trip · If possible a preliminary trip should be made; this trip can be made by the teacher alone or with a committee of children. One of the first things to determine at this time is how much the children should see during the trip. Some places offer so much that it is impossible for the children to see it all at one time. There is also the possibility of undue fatigue or loss of attention. In such cases it is necessary to decide which things the children should see that will best achieve the purpose of the field trip. A second trip can always be made later if additional information is necessary.

Look for any safety hazards that may exist. Safety is one of the prime factors to be considered when making any field trip. Many teachers take a small first-aid kit during the field trip. Make a list of precautions, which should be discussed in great detail when planning with the children for the trip.

Find out if there are any special demonstrations that will be performed or if any films will be shown as well as what time they will be offered. If free materials are available for distribution, make sure there will be sufficient copies for all the children. Some places offer materials for sale. Make

a list of these materials and their cost so that the children may come prepared to buy them.

Have a conference with the guide or personnel member who will act as guide. This conference is very important. Tell the guide the purpose of the field trip and describe the science unit in progress. Suggest aspects that the guide should stress when the children come. Remind the guide of the grade level of the children and urge strongly that the talk be kept at the level of the children's understanding. Otherwise there will be no value in having a guide. If possible, the teacher should supply the guide with a list of anticipated questions the children will raise or want answered.

For the children's convenience, the teacher should find out where the rest rooms and drinking fountains are. If the field trip will take all day, there is the problem of lunch. Some industrial plants, museums, and zoos have lunchrooms. Other places may not have cafeterias but do provide a room where the children may eat lunches they can bring. Most places, when consulted, will offer suggestions about the children's lunch because they will have been asked about it before.

PLAN WITH THE CHILDREN FOR THE TRIP

Pupil participation in planning the trip is an essential part of the learning experience to be gained by taking the trip. The children will feel that it is their trip, and, because they have worked cooperatively and democratically in planning, the trip should proceed more smoothly. It is also likely that a greater amount of learning will take place.

The children can play an important part in planning the trip. Some of the children can accompany the teacher on the preliminary trip and help the teacher with the preliminary investigation and planning. Others, or even the entire class, can help compose and send a letter asking the owner of a private concern for permission to visit. The children can discuss and agree upon the proper conduct and behavior to be maintained while they are on the trip. Discipline is much easier to maintain when the children clearly understand the rules, and especially when they themselves have helped draw up these rules. This discussion should encompass proper behavior and courtesy not only for the time the children are traveling to and from the place to be visited, but also for the time they are at the place itself. This determination of rules of conduct helps in maintaining good relationships, and ensures continued permission to visit the establishment.

In all field trips the teacher must be constantly concerned with two things: preventing accidents and making sure that no one strays or gets lost. Discuss both factors with the children, especially potential hazards. Have the children select leaders or lieutenants to assist the teacher. These assistants can help take attendance when needed. Each may be put in charge of small groups during the trip, with instructions to watch out for accidents or lagging. One or two of the assistants may be in the rear while the teacher remains in front with the guide, or vice versa. The "buddy" system, as in swimming, may also be used to advantage.

Let the children help decide what they will see or do on the field trip.

The children are quick to understand that not everything can be done in one day. Otherwise the trip will be hurried, and the value of taking the trip may be lost. Help the children draw up the list of questions they want answered and the items they want to see. They should try to make the questions as explicit as possible so that the answers will be definite and to the point.

Give specific assignments to individuals or small groups · Giving specific assignments to individuals or small groups is one of the most effective ways of ensuring that the field trip will be successful as a learning experience. Most persons, after they have visited a museum, for example, usually leave with two impressions: first, that they have seen a great many things and, second, that they are fatigued. This reaction is common in adults as well as children. But, although they have seen many things, they are able to recall only a few items vividly. The rest is rather vague. This phenomenon explains why so many teachers are disappointed in field trips. The children may have seemed to learn a lot during the field trip, but they can recall comparatively little during the follow-up in class the next day.

The situation can be remedied substantially by assigning individuals or small groups to observe or listen to certain things, which they will report to the class the next day. This method is an excellent way of really involving the children in planning the field trip. After the children have made up a list of questions to be answered, specific questions can be allocated to each child, or to small groups if there are not enough questions to go around. Each child now has a definite responsibility. During the field trip the child will still observe everything closely, but he will pay special attention to the material that will provide the answer to the assigned questions. Actually, this method is better than giving each child a checklist of all the questions to be answered. Sometimes the children become so involved with the checklist that they do not have an opportunity to see what is going on or to get the whole picture.

Have a follow-up · Follow-up should be provided as soon as possible after the field trip if the learning experience is to be worthwhile. When the children are in class the next day it would be wise to recall first the purpose of the trip and to talk about the highlights or unusual things the children saw or did. Then the list of questions to be answered would be reviewed, followed by oral reports from the individuals or small groups who were assigned to find the answers to specific questions. This procedure is an excellent way to establish understandings, bring out relationships, and arrive at conclusions.

During the follow-up the teacher should be prepared for new questions that may be raised as a result of the field trip. If these questions are related to the unit being studied, they will pave the way for further learning in the unit. If the questions are in areas that are unrelated to the present unit, they may provide excellent leads for the study of new units later. In either

case these new questions will be helpful to the teacher for further learning by the children.

The follow-up is an excellent time for the teacher and class to prepare a letter thanking the persons responsible for the field trip. At the same time behavior on the trip can be evaluated, and future plans can be developed for avoiding any unpleasant situation that may have occurred. Under no circumstances should the follow-up be a test. This procedure is sure to ruin the field trip for the children and destroy interest in future trips.

Integrate the field trip with the other phases of the elementary school curriculum · When properly handled, the field trip should be an integral part of the daily program. Certainly the field trip will call for further reading. There will be oral and written reports, and letters to write. Most of the materials in field trips carry implications for social studies. In some cases there will be a need for problems in arithmetic and the development of simple ratios. In the lower elementary grades particularly, there will be occasion for art and poster work.

LIMITATIONS OF FIELD TRIPS

Many teachers dislike taking field trips, especially the longer ones. Several disadvantages are offered, some of which are more valid than others. Occasionally, for instance, school administrators disapprove of field trips. Or teachers may find that they are unable to take the trip at the desired time during the unit because many establishments are so popular that reservations must be made weeks or months in advance. Some places are small and cannot handle large groups of class size. This limitation means that the class may have to be broken up into two or more groups, with the resulting lack of teacher supervision or control.

Some places encourage field trips but are not geared to give the children full or adequate learning experiences. They may use personnel who are either untrained or do not have the aptitude to be guides. Consequently, they are unintelligible to the students. In some cases demonstrations may be given in rooms where it is impossible for all the children to gather around where they can see and hear what is going on. As a result, only those children in front can take full advantage of the experience, while the others become bored and restless.

One strong objection of teachers to field trips is based on their unwillingness to risk the possibility of accidents to the children. Even with the best supervision and precautions, when a large group is taken through the streets, on buses or in cars, a safety hazard is introduced. There is also the possibility of accidents in factories and other such establishments. Many teachers who can handle large groups in the school building without any difficulty become quite distraught during field trips and dislike the emotional stress and strain involved.

Although many of these objections are sound, their solution is not insurmountable. They should not discourage the teacher from taking any field trips at all. There are so many possibilities for field trips that the

Using resource persons.

teacher can surely select those where the above disadvantages do not exist or are at a minimum. To provide for safety, careful planning with the children and all others concerned will help greatly in preventing accidents.

Resource Persons

EVERY community, large or small, urban or rural, has a large number of people that the school can call upon to serve as resource persons when the children are learning science. These persons are able to bring a wide variety of special information, experiences, skills, and even hobbies into the classroom. Many teachers apparently have not yet learned to take advantage of this opportunity, and by so doing are failing to utilize an excellent teaching technique.

When resource persons come to the classroom it is much like taking a field trip, except that now the field trip is brought to the children. The use of resource persons as a teaching technique is also less complicated and more easily manageable than taking a trip. It does not disrupt the school schedule. No time is wasted in transportation. All the problems of transportation, together with the possibilities of accidents during transportation or at the site of the field trip, are eliminated. The resource persons can come at the exact time they are needed during the unit. All the children are

able to see and hear clearly, without distractions, and can give the persons their undivided attention. A disadvantage of using resource persons, however, is that the children are likely to see less and listen more than when participating in field trips.

There are all kinds of persons that can be used for resource purposes. Examples of such persons include scientists, doctors, veterinarians, dentists, gardeners, representatives from industry, labor, and public utilities, members of local and state public works departments, and even artists and musicians. Science teachers and professors are excellent sources that can be used. Wherever possible, the teacher should try to get a resource person who is also a parent of one of the children in the class because using the parent in this way helps the parent realize and appreciate the learning that is going on in the classroom. No matter who is asked, the person is generally willing to come into the classroom to demonstrate, exhibit, talk, discuss, answer questions, and share what he knows with the children. Furthermore, the children will become quite excited at the prospect of having a real scientist, pilot, or engineer come to visit them.

Resource persons can be used in exactly the same ways as field trips. They may be used to introduce or arouse interest in a new science unit, supply answers to questions and problems raised during a unit, or provide a culminating activity at the end of a unit. In whatever way the persons are used, there should be a definite purpose for bringing them into the classroom, and this purpose should be clearly understood by all the children.

Before the children invite the resource person, the teacher should contact the person to find out if the person will be available and what days and hours are suitable to come. Describe what is being learned in class and state what information will be desired. Give the person an idea of how long the visit should be and decide together how much material could be taken up during that time. Above all, be sure to tell the person the age level and maturity of the children, and urge that the person's vocabulary be geared to the level of the children.

There will be much planning for the children to do. They can help select the resource person, and then either send a committee to invite the person to the classroom or write a letter of invitation. One child may be elected to wait for the person in the principal's office, and another child may be given the privilege of introducing the person to the rest of the class. Conduct and courtesy while the person is speaking must be discussed and agreed upon. The children should draw up a list of questions that they would like answered. Just as with the field trip, the teacher can give individuals or small groups the responsibility of obtaining answers to specific questions, which they will report to the class either the same day or the next day. This is likely to give the resource person a pleasant surprise. So many persons offer stimulating demonstrations, talks, or discussions, but, when a question period follows, often there is little or no response from the audience. This reaction is always disappointing to the person, and the entire presentation diminishes and ends on a low note. When the children have

specific questions to be answered, however, and either do not have all the information they need or do not understand something the speaker has said, the children will bombard the resource person with further questions after the person has finished speaking.

A follow-up should be conducted as soon as possible. The individuals or small groups who were assigned to find the answers to specific questions will now report their findings to the class. Important understandings should be listed, relationships established, and conclusions drawn. New questions that arose as a result of the visit by the resource person can be used as leads either for further learning in the unit or for introducing new units. Finally, a letter of thanks should be written and sent to the resource person.

Audio-Visual Aids

ANOTHER method of teaching science uses audio-visual aids. This term is very broad because it actually includes visual aids, audio aids, as well as a combination of the two. Visual aids, of some kind, have been used in education as long as education has existed. Audio and audio-visual aids were not developed until the advent of the radio and the sound film. The sound film has become so popular in schools today that many teachers, when the term audio-visual aids is mentioned, usually think first of sound films, and then possibly include filmstrips as an afterthought. Actually the term audio-visual aids refers to many mediums, all of which, when properly used, can be powerful teaching techniques. A list of potential audio-visual aids would include such materials as films, filmstrips, slides, pictures, models, specimens, charts, graphs, posters, radio, recordings, and television.

Films

WHEN IT is not possible for the children to obtain firsthand experiences with materials and phenomena, the next best thing is to provide these experiences vicariously. The film is a teaching device that more than any of the other devices achieves closeness to reality. As a result, the film has become one of the most widely used teaching aids in our schools. Like the field trip, the film can provide experiences that cannot usually be brought into the classroom, show materials and phenomena in their true or natural relationships, and explain in greater detail how the basic science information applies to the children's environment. Unlike the field trip, it does not disrupt the daily program, consume valuable time in transportation, or risk the possibility of accidents. It does, however, enable the children to see and hear everything clearly, many times if necessary, without distractions.

There are many films available to the teacher on all levels, produced by industrial concerns, public service organizations, museums, and state and federal departments. The quality of most of these films is good. Many publishing companies now provide films that accompany their textbooks.

Often a teacher's guide comes with the film, giving background material and suggestions for additional activities or reading. Most state departments of education and state universities or teachers' colleges have film libraries, and they will send films free or for a very nominal charge. These institutions, as well as those institutions described above, provide catalogs upon request. Many large cities have their own film libraries for distribution to the teachers in their school systems.

Another unique source of films comes from the teachers themselves. Because of the growth in popularity of the home movie camera, many teachers use it to photograph special experiments or demonstrations, objects and places that are too far away for a field trip, and other experiences that would be of interest and value to the children.

WAYS OF USING FILMS

Introducing a unit · When used to introduce a science unit the main purpose of the film is to arouse interest in the science topic to be studied and raise questions to be answered or problems to be solved. Therefore, the films to be used for this purpose should be general in nature. If the films are specific rather than general, they are likely to furnish the answers to questions before the questions can be asked, or they may solve problems before there is an opportunity to raise them; therefore, the interest of the children would be stifled, and the purpose of using the film at this time would be defeated. The film would not create a learning situation, but it would become the learning situation itself, under conditions which would not be conducive to effective learning. Since most films contain both general and specific information, only the portion of the film that shows the general information should be shown to the children whenever the film is used to introduce a unit.

Obtaining information during the unit · Films can be used to obtain many kinds of information during the unit. They can help the children answer questions, solve problems, and check previous experiments, reading, discussion, and conclusions. If the class is unable to go on a field trip when required, a film may be used instead. Although the film does not really take the place of a field trip, it can approximate the trip. When teachers have limited supplies and equipment, or if the classroom facilities are inadequate, a film may be used for performing experiments and demonstrations. It can also show phenomena that cannot be seen under the ordinary magnifying glass or microscope. Here again, the teacher need not show the entire film, but only the portion that pertains to the experiment or demonstration. When a film is used as a field trip, experiment, or demonstration, the teacher should follow the same kind of planning, preparation, and suggestions that would be appropriate if the real activity were being performed by the children or teacher.

Culminating the unit · When films are used as culminating activities, they help summarize and review the important understandings of the science

topic the children have studied. This use of the film helps the children fix the understandings and their relationships to each other and the environment firmly in their minds. A film will often help the children get a clearer and more vivid picture of the things that they have learned and read about because it operates in real life situations in their proper proportion and environment.

Using films to evaluate · In certain situations films can be used as an evaluative technique. In this case the teacher merely turns off the sound portion of the film and asks the children to describe or explain what is happening. This operation can be done for specific portions of a film or, if the film is short, for the entire film.

SUGGESTIONS FOR USING FILMS

There should be a real purpose for using the film · Too many teachers show films either because the films are easily available or because it is considered good teaching to use films in the classroom. Just as with experiments, demonstrations, or field trips, there must be a purpose in showing the film. This purpose should be clearly understood by all the children. In this way the film becomes an integral part of the unit, designed to introduce the unit, obtain information during the unit, or serve as a culminating activity at the end of the unit.

Select the film carefully · Is the film designed for the children's grade level or ability? If it is not, the entire value of the film may be lost. Does the content of the film bear directly upon the science topic being studied, and will it yield the desired information or produce the intended effect? Check the date when the film was produced. If the film is very old, the outdated clothing worn by the persons in the film may produce enough mirth to interfere with the purpose for viewing the film.

It is helpful to make a card file of all potentially useful films. Catalogs may be obtained from commercial film distributors, film companies, and state and federal departments that provide film services. From these catalogs the teacher can obtain the following information, which may be put on each card: the title of the film, the name of the producer, where the film may be obtained, whether there is a fee to be paid, the grade level for which the film is designed, how long it takes to run the film, and whether the film is in color or black and white. After the film has been used in class, the teacher can add to the file card a brief evaluation of the film for accuracy of content, clarity of explanation, and appropriateness of grade level. She should also add a statement indicating whether or not the film should be used again.

Preview the film · The film should be previewed whenever possible. Many times the brief description in the film catalog does not give a complete or true picture of the contents of the film. Sometimes the designated grade level of the film is questionable, and the film may be either too

simple or too complicated. By previewing the film the teacher becomes completely familiar with its contents. The teacher can then decide whether all or a part of the film should be shown, and which parts may be complicated or important enough to warrant repeating. By previewing a film the teacher also can learn if the film will answer the children's questions. At the same time the teacher can anticipate further questions that might be raised.

Plan with the children for viewing the film · Just as the field trip or any of the other methods of teaching science are planned with the children, the viewing of the film should be planned with the children. When the children are not involved in the planning, they often look upon the film as a means of entertainment rather than as a learning situation. The reader may recall classroom situations where the teacher unexpectedly announced that a film was to be shown—and the announcement served as an immediate signal for everyone to sit back and relax. The film was an unexpected, and probably welcome, respite or vacation. While watching passively, in a darkened, warm room, the pupils became drowsy, especially if the film was long. When the lights were snapped on, the class was dull and sluggish, and not in a mood for discussion or review. Only a few persons could recall the important points of the film or answer the teacher's questions.

The results are very different when the children are involved in the planning. They can help select the film. They can draw up a list of questions to be answered or points to be noted. Here, too, the teacher should assign specific questions to individuals or small groups. While the film is being shown, these children will now have the responsibility of getting the answers to these questions, which they will report to the rest of the class after the film is over. The children can even help the teacher evaluate the film.

Have the film ready to be shown · If the teacher begins to set up the equipment for showing the film at the last minute, often the tempo of the whole lesson may be broken. Sometimes the teacher is ready to show the film at the appropriate time in the unit and finds that the equipment is not available or out of order. To avoid this the teacher should make sure the projector and screen are reserved for the desired time. The film can be threaded in advance, and the projector can be tested and focused properly. The screen and projector should be placed a suitable distance apart from each other so that the picture fills the screen. At the same time the screen should be placed at a height convenient for all the children to see comfortably and clearly. Place the speaker in the best possible position, facing the class, and adjust the volume of the sound. Then get the room ready for quick darkening.

Have a follow-up · It is important that the follow-up take place as soon as the film has been shown. The answers to the questions assigned to individuals and small groups can be given and put on the chalkboard in a

logical sequence. Discussion is an important part of the follow-up. Discussion is where understandings are established, relationships developed, and conclusions drawn. During the follow-up new questions may be raised, which will lead either to further study in the same science topic or exploration into a new science topic.

The film may be shown more than once · Repetition is often necessary or desirable when the film is either very long or highly appropriate. If the film is long, the children's attention span may determine whether the film should be shown a second time. To show a film twice, with discussion sandwiched in between, is often an excellent way of having the children fix the science understandings firmly in their minds. Sometimes only a portion of the film may be shown a second time, and even a third time if it seems necessary. Very often teachers will turn off the sound, when a film is shown a second time, and substitute their own narration. The teacher narration is often more effective than the original sound because it can be stated in simpler terms, directed specially at the children's questions, and show relationships and conclusions that are being sought.

DIFFICULTIES IN USING FILMS

Although the use of films is a valuable teaching technique, there are difficulties that have tended to discourage many teachers from using films as often as the teachers would like. The biggest and most frustrating problem is getting the film at the desired time. Because the demand for films is so great, it is usually necessary to order the films far in advance. In many cases teachers are required at the close of the school year to submit a list of the films they would like for the following year. This requirement means that the teachers must predict a year in advance exactly when and where the various teaching units will be in progress, which is something that is almost impossible to do. Even then there is no assurance that the teachers will get the films they ordered, owing to the heavy demand. This demand for films is also true of school systems that maintain their own film libraries. So many teachers want the same film for the same week. Since all orders for films are filled in order of receipt, many teachers must be disappointed, and therefore have to do without the films ordered.

Films are customarily loaned to a school for one week. Often several teachers would like to use the film during this time. When this crowding occurs, not only have the teachers had no opportunity to preview the films before ordering them, but also many teachers are pressed to find the time to preview the films before using them in class. The limitation of using the film for only one week prevents many teachers from using different parts of the film for special purposes as the unit progresses. Some teachers hope to use one part to introduce the unit, the second part to answer questions during the unit, and perhaps the entire film to review the unit as a culminating activity. Usually the teacher must return the film before it can be used for all three purposes.

Conditions within the school may make it difficult to show films. Some

Filmstrips are valuable teaching aids in learning science.

schools may have a very limited budget for films. Very often the classrooms cannot be darkened. Some schools have only one movie projector available and cannot meet the demand for its use. Many teachers have difficulty in operating the projector, especially if it is old. As the projector becomes worn, the sound system begins to weaken. The voices in the film may sound fuzzy or cracked. If the synchronization between sound and the picture is bad, the teacher will encounter the ludicrous situation of having the sound appear a few seconds after the commentator or persons in the film have begun to speak.

Once the film starts, it must keep moving. The teacher cannot stop at a certain frame of the film for comment or discussion because the heat of the projector will cause the film to melt. If the teacher wants to show only one part of the film, and then show this part a second time, there is the problem of rewinding the film when it is only half run off. The children must wait until the entire film is shown before they can raise questions.

Filmstrips

FILMSTRIPS are particularly suited for use in the elementary school. They can be used in exactly the same ways as films, namely, to introduce or arouse interest in a science unit, obtain information during the unit, and serve as a culminating activity at the end of the unit. A filmstrip lends itself

more easily than the film for use as a test. With filmstrips the teacher merely shows the desired frame to the children, using a strip of paper or cardboard to hide the caption at the bottom of the frame. There is also the added advantage of being able to show the frame to the children for as long as necessary.

The suggestions for using films is also applicable for using filmstrips. There should be a real reason for using the filmstrip. It should be selected carefully and previewed. The children should be involved in planning to use the filmstrip. A follow-up is necessary, and the filmstrip or portions of it should be shown as often as necessary. When it is the proper time to show the filmstrip, everything should be set up and prepared.

Many elementary teachers prefer to use filmstrips rather than films because of the many advantages of filmstrips. Filmstrips are relatively inexpensive and therefore are purchased rather than rented by the schools. This purchase makes them the permanent property of the school and easily available at all times. As a result they can be used at the right time during the unit, and for as long as is necessary. The teacher can stop at any frame and keep that frame on the screen while the teacher and the children speak, have discussions, and answer or raise questions. The teacher can skip back one or more frames without any trouble, or go forward in the same way. All the frames in the filmstrip are numbered, and, by knowing what is in each frame, the teacher can select any combination of frames to be shown. Turning the knob of the filmstrip projector quickly will blur the other frames enough so that the children will not learn some of the material too soon or out of context with the learning in progress. Even filmstrips designed for the junior or senior high schools can often be used to advantage in the elementary school. In this case the elementary teacher simply selects the frames that will be of use to the children and restates the captions underneath in simpler terms.

Filmstrip projectors are much less expensive than movie projectors. Consequently, there are usually several in the school instead of just one. They are easy to operate, and there is less chance of anything going wrong with the machine. Small filmstrips viewers, which do not need a screen, are now available, and they can be used by looking directly into an eyepiece. They are so inexpensive that one could be provided for each classroom. With such a viewer, filmstrips can be used by the children just like other supplementary textbooks or reference materials. The children could go to them to get the desired information whenever necessary.

Filmstrips do have a few disadvantages when compared with films. The chief disadvantage is the lack of motion, with the resulting loss of sense of immediacy and the inability to see the necessary motion or changes involved in many scientific phenomena. Sometimes the fixed sequence of the filmstrip is a disadvantage, especially if the sequence is not suitable. This factor can be partially compensated, however, by showing the frames to the children in a sequence other than the original. It may require some ingenuity and turning of the knob, but it can be done.

Slides and Pictures

THE USE of slides in the classroom, especially the 2 × 2 slides, has been increasing steadily because of the present popularity of photography. Teachers now take pictures that have scientific value and interest. These pictures may be taken within and in the immediate vicinity of the community, or while the teachers are away on vacation during the summer. Many teachers who have very little experience with photography are able to get cooperative persons in the community to take such pictures for them. Commercial companies are now putting out 2 × 2 slides for classroom use. There are several advantages to using these small, individual slides. The slides can be arranged in any order the teacher prefers. They can be made by either the teacher or the children. Because the pictures have been taken by the teacher or children and often contain items and materials that are indigenous to the community, the slides have a personal touch that creates added interest in the classroom.

The use of pictures in the classroom can be of great value in introducing a science unit, by arousing interest and raising questions or in keeping interest alive while the unit is in progress. These pictures should be selected carefully, with distinct purposes in mind. The pictures should be clear, accurate, and be able to stimulate the imagination and arouse interest. Pictures that satisfy these requirements can usually be found in such magazines as the *National Geographic Magazine* and *Life*. Such pictures can be posted on the bulletin board or projected on a screen by an opaque projector. Teachers should start building a collection of worthwhile pictures and keeping them in a file in the classroom, classified under appropriate titles or headings. A legal-size filing cabinet may be necessary because many of the pictures are large. If a cabinet like this is not available, fruit crates or wooden boxes of suitable size may be used instead to make the picture file.

Models, Specimens, Charts, Graphs, and Posters

VISUAL materials such as models, specimens, charts, graphs, and posters are readily available from scientific supply houses. Although teachers should buy some of these, there is much to be gained when the children themselves collect or make most of them. For example, in preparing a display of specimens and homemade models, the children will have to do much reading, planning, and discussing. Measurements will have to be made to scale the models properly. In the process much learning of basic science information will take place, as will also be true when the children make the charts, graphs, and posters. Setting up the display will involve arranging and labeling, which will help the children develop an understanding of classification and relationships. The best of the materials can be

Making homemade models.

saved by the teacher for use when teaching future classes. In time an accumulation of such materials can form the nucleus for a small science museum in the school.

Radio, Recordings, and Television

RADIO

From its beginning radio has been used as an aid to teaching and learning in the classroom. Many radio stations, especially in the larger cities, allow school systems and state departments of education to produce programs specifically planned for the schools. The programs devoted to science include animal tales, biographies of famous scientists, stories about important scientific discoveries, science in the news, health and safety talks, and many more topics in every area of science. Other programs, not directly planned for school use, may also contribute to the children's learning. Thus radio offers educational opportunities, both during and out of school hours.

The use of radio in the classroom has many advantages. The material can be presented by an expert who is skilled in making science exciting and easy to understand. The program can reach a large number of children at one time. Many radio stations that produce programs for school use give advance notice of the programs, and the teacher can prepare the children for listening to the broadcast. Some stations provide teachers' manuals that give the background for the program and also many suggestions for experimenting, discussing, reading, reporting, and other activities that can follow the

broadcast. Leaflets are sometimes prepared for the children which contain pictures and diagrams, outlines, and questions to be answered.

On the other hand, there are some limitations in using the radio as a teaching aid. The program is given just once and, if missed, cannot be recaptured unless it has been recorded on a tape recorder. Perhaps some of the children have not acquired the science background that would prepare them for the program at the time it is broadcast. Once the program has started, it cannot be stopped for questions, discussion, or clarification. Because the communication is only one way, there is no opportunity for the children to question the participants in the program.

Suggestions for using the radio as a teaching technique are fundamentally the same as those for the other techniques. The children must be prepared for the radio program. Thought-provoking experiments, demonstrations, questions, or pictures may be used to raise questions or problems that will be answered by the radio broadcast. Specific questions can be assigned to individuals or small groups. When the program is on the air the children should be seated where they can hear everything clearly, and the volume should be properly adjusted. There should be a follow-up to the program. The highlights of the program can be reviewed, and the answers to the assigned questions reported and summarized. New questions that arise can lead to further experiments, reading, discussing, or reporting. In the follow-up it may be instructive if the children evaluate the program and compare it with previous programs.

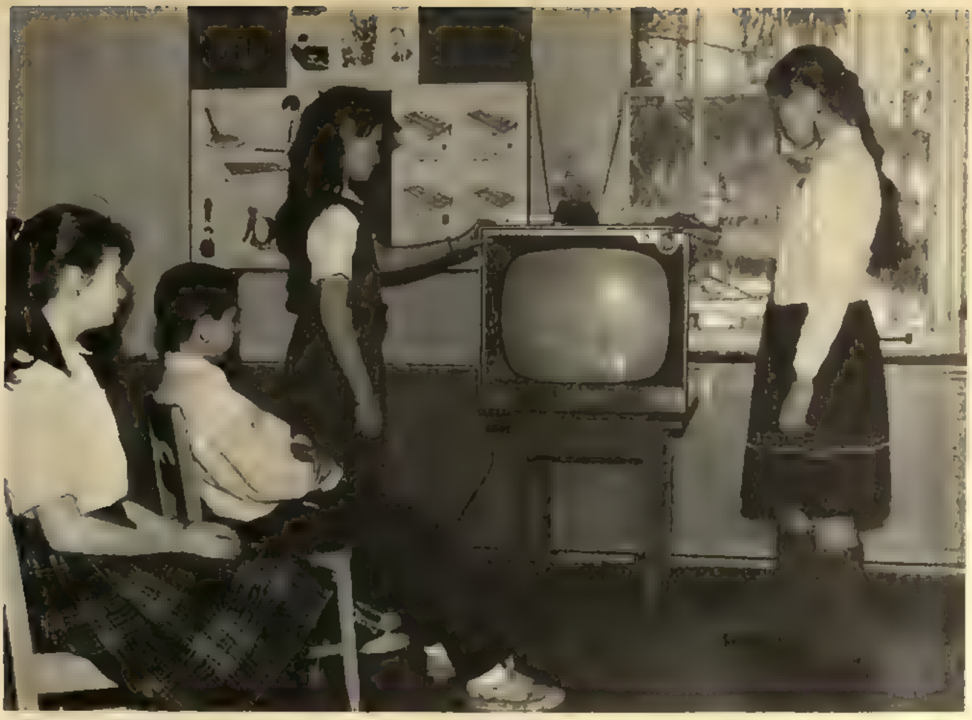
RECORDINGS

Tape recordings can be helpful in taking down radio programs, school programs, talks by guest speakers or resource persons, and even the audio portion of a television program. The transcription can then be used exactly when needed in the classroom, repeated as often as necessary as well as stopped at any time for questions and discussion.

With the advent of the long-playing record, another teaching aid has become available for the classroom. Phonograph records can now be used in much the same ways as radio programs. Many industrial and public service companies have begun to make records for classroom use. Booklets containing coordinated reading material are distributed to the children; the booklets are to be read while the record is being played. Filmstrip companies now offer filmstrips that are used in conjunction with records.

TELEVISION

Television has captured the imagination of everyone as a potential teaching device and consequently is receiving universal support. The acceptance and support of television is bolstered by the unusually high appeal it has for the children. No other audio-visual aid has ever received as much recognition and attention in so short a time as television. Television sets are now found in schools throughout the country. Large sums of money are being spent for experimental programs in schools and colleges to explore all possible means of using television in education. Educational television



Using television in the classroom.

stations have been set up in several universities and colleges. Some of these stations are closed circuit whereas other stations are open to the public as well. Many high schools and school systems have their own closed-circuit television. Industrial concerns sponsor programs of educational value on commercial stations at hours suitable for home viewing.

The advantages of using television as a teaching device are numerous. Television is the only medium that allows its viewers to see historical events, important happenings, and discoveries as they are made. It is also particularly appropriate for giving children and the public current information about progress in science. It is able to create the illusion that the viewer is sitting beside the scientist as he demonstrates and explains his findings. Children can watch a rocket sent into space and, with the help of the scientist, learn more about rockets and space travel than might be accomplished by hours of unguided reading and study. Values such as these place television high above all the other audio-visual aids.

Like the film, television can give the children a direct view of experiments and demonstrations. It can use equipment that is unavailable in many schools, and it has the added economic factor of using only one set of apparatus or equipment. Explanations are given by experts in science, who at the same time understand children and know how to teach them. It can incorporate and use all the other audio-visual aids in its programs.

However, although a good film can be seen effectively by only one or two classes at a time, television can be seen by as many children as possible.

This eliminates the frustration of teachers who have to order films well in advance, the disappointment of not being able to get the film, and the inconvenience of receiving films at unpropitious times. Television programs can also be geared to the textbooks and courses of study in the schools.

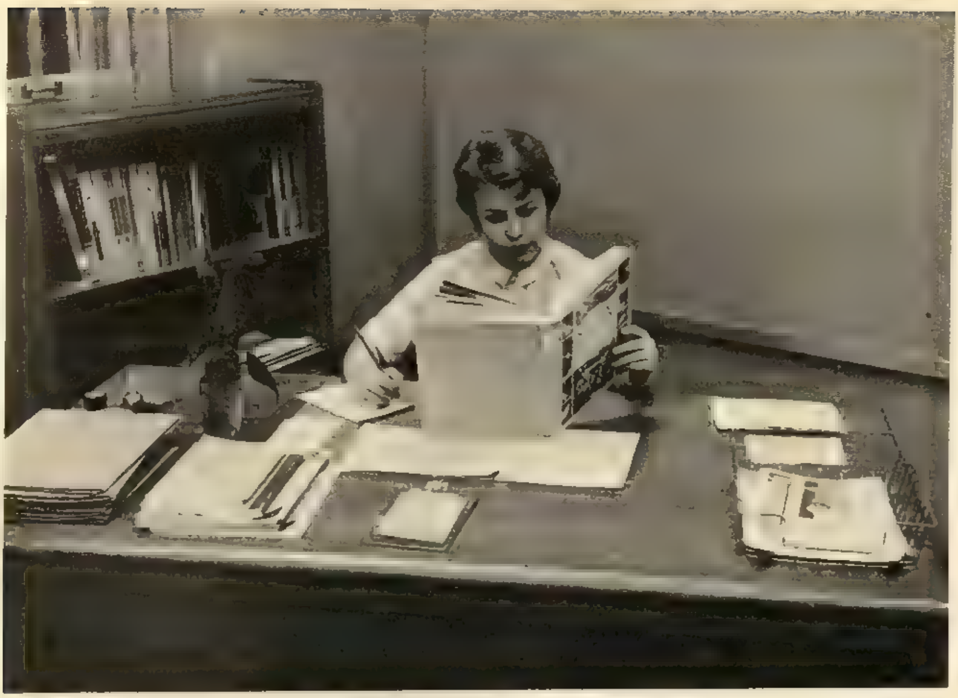
Television can be of indirect benefit to the children by providing opportunities for in-service education of the teachers. This use may eventually be the most valuable contribution of television to education. Programs can be used to enrich the science background of the teachers and to keep them informed of the latest developments in science. Programs can also familiarize the teachers with the tools and methods of the scientist, and suggest ways and means of increasing their effectiveness as science teachers. Such programs can do much to overcome the reluctance of many elementary teachers to teach science because of an inadequate science background and an unfamiliarity with science equipment. Teachers, as adults who can think abstractly, are also better able than the children to cope with the difficulty of using a technique like television, which only communicates one way.

Television also has limitations. Many schools have television sets with picture tubes 21 to 24 inches in size. This size may be adequate for the children sitting in front, but the picture will be small to those sitting in the back of the room. Experts generally agree that the minimum screen size acceptable for classroom use is 40 inches. Is it surprising, then, that children, who must view television programs in auditoriums containing a standard set, become bored, inattentive, and restless? Another limitation is that the program is given just once, and it must be used at the time it is presented, regardless of whether the children have the necessary background and preparation for seeing the program. Once the program starts, it cannot be stopped at any point for questions or discussion. Sometimes teachers are given no advance preparation or preview of a program to be shown. This lack of preparation creates an awkward situation for the teacher when the program is over, particularly if the program is in an area of science that is not very familiar to the teacher.

Television programs working successfully in school systems use a basic format. The program is geared to the textbook and course of study. Teachers' manuals or guides have been prepared and distributed to every teacher involved in the program. These guides contain background material for the teacher and children and a preview of each program. The teacher is thus able to prepare the children for seeing the program in much the same manner as for any other teaching technique. When the program is used to introduce a unit by raising thought-provoking questions and problems, suggestions are given in the guide for further experimentation, reading, discussing, reporting, or other suitable activities. The same is true when the program is used to supply information during the unit. As a culminating activity, the program reviews the highlights of the unit and provides leads for new units. Many school systems supply the children with leaflets containing notes, pictures and diagrams, questions, and things to do.

When programs are operated in this manner, they serve to strengthen

the function of the classroom teacher. The teacher now becomes even more strongly the center and director of learning in the classroom. After the television program has been shown, the teacher assumes control. The teacher asks pertinent questions, participates in raising problems, conducts discussions, suggests different ways of obtaining information, helps draw conclusions, and evaluates the work of the children. Thus, television does not and cannot replace the teacher, but it acts as a powerful teaching device to supplement the work of the teacher.



CHAPTER 5

Planning *for* Science *in the* Classroom

PLANNING is a major prerequisite for successful teaching. This fact may not be immediately evident to many who observe an experienced and skillful teacher in action. The science lesson may seem to develop so extemporaneously, often without any visible evidence of lesson plans or unit plans, that the observer at first thinks that no special planning was involved. However, as the lesson progresses, the observer gradually becomes aware that learning is taking place in a logical, well-defined way. The problems that have been raised are being solved. The materials necessary for experiments or demonstrations appear or are available in the right place at the right time. When references are needed to find information or check conclusions, the books are ready.

The observer now realizes that this kind of teaching and learning occurs only as a result of intensive planning and preparation. And if there are no lesson plans or unit plans in evidence, it is not because these plans have not been carefully constructed. It is likely that, over a period of years, the

teacher has devoted much time and effort to planning, and now she no longer needs the specific plans at her side when teaching. A brief review the night before, together with planning to provide the necessary materials and references, is all that is necessary to be prepared for the class the next day.

What kind of planning is necessary for successful science teaching? The teacher must plan to become completely familiar with the basic science information pertinent to the topic being studied. This familiarity with the material is absolutely necessary if the teacher is to be the guide and director of learning in the classroom. Only by acquiring a thorough understanding of the key concepts can the teacher know which concepts are relevant to the topic, which concepts the children can learn at a particular grade level, which concepts should be deferred for a later grade level, which concepts will evolve from each learning activity, what relationships exist between the concepts within the topic, and what interrelationships can be found with concepts in other science topics.

The teacher must look for a wide variety of appropriate learning activities, and then select those that will most effectively teach these science concepts. These activities may include experiments, demonstrations, reading, discussion, reports, films, filmstrips, field trips, or speakers. If the experiment is unfamiliar, the teacher must try it in advance. If the film is new, it must be previewed. Supplies and materials must be collected or assembled. Textbooks and references must be readied for consultation.

Suitable activities must be found that will initiate pupil curiosity, interest, questions, or problems. These activities are the ones that get the children involved in the learning situation. Plans must be made to develop such desirable behaviors as scientific attitudes, critical thinking, abilities and skills, appreciations, and interests. Special attention must be given and provisions made for slow and fast learners. Time must be allowed for the slower pupils to absorb and completely understand the science concepts. Additional activities and projects must be made available for both slow and fast learners.

Provision must be made for evaluating the learning that is taking place and the desirable behaviors that are being developed. The teacher must strive for the best possible means of communication with the children because communication, too, is a prerequisite for successful teaching. Finally, the teacher must plan, not for just one day's work at a time, but for a complete unit of work, with definite scope and sequence. In this way the teacher can review what has gone before, and plan for what will come in the future. At the same time it will ensure an even and uniform learning sequence, with no embarrassingly short or overly long science periods.

The Unit

CONCOMITANT with the need for planning is the need for organizing the elements of good planning into a suitable framework, through which the

Arousing pupil interest.

teaching-learning situation in the classroom has scope and sequence. A highly effective means of organizing such a framework is the unit.

The unit is a logical division of class work or activity. When constructed, the unit becomes an *anticipated* plan for using a wide variety of activities and materials so that learning can take place. The objectives of the unit are to help the children learn basic science information and develop desirable behaviors. As stated before, the term *basic science information* is used broadly to include science facts, understandings, generalizations, principles, laws, concepts, and conceptual schemes. And the term *desirable behaviors* includes abilities and skills (both functional and mental), scientific attitudes, appreciations, and interests. Thus, the unit presents a plan for providing learning activities that will achieve the objectives of the unit.

When planning and constructing the unit, the teacher selects the objectives, develops the means for arousing pupil interest and problems, anticipates a logical sequence of learning activities, provides for the necessary laboratory and reference materials, and even gives consideration to the possibilities for evaluating both the learning and the desirable behaviors that the children will gain. The teacher strives at all times to give the unit suitable scope and sequence.

Although the unit is developed in a logical sequence, it should not be rigid. It must be flexible enough to permit digression at any point, if necessary, without interrupting the broad pattern of learning anticipated by the unit. It is necessary to plan the day's work in advance, but the

plan should be pliable enough to include and incorporate new situations and questions as they arise.

What to include in a unit is always a matter of discussion. Proponents of the various types of units differ somewhat about content and organization. However, it is generally agreed that a unit should contain most—if not all—of the following:

1. Overview.
2. Teacher's objectives.
3. Initiating activities.
4. Pupil objectives.
5. Learning activities.
6. Materials.
7. Bibliography.
8. New science vocabulary.
9. Culminating activities.
10. Evaluation.
11. Work sheets.

A detailed discussion of each of these components of a unit follows.

OVERVIEW

The purpose of the overview is to describe the nature and scope of the unit. Some teachers or school systems, when constructing units, omit the overview. However, the overview can serve a definite purpose. When a school system sets up a science course of study and constructs units, it is likely that a science committee or workshop group is given the responsibility of preparing the units for the rest of the teachers in the school system. This preparation will result whenever a school system is large and has so many elementary school teachers that it becomes impossible to involve all the teachers in constructing every unit for each grade level. Furthermore, with the consistent rapid turnover of elementary school teachers, there will always be new teachers or beginning teachers who have started teaching after the units have been constructed. In such cases, whenever units are presented to teachers who have had no part in constructing them, it is always helpful to provide an overview with a brief description of the nature and scope of the unit. Even when the teacher makes her own unit, an overview can be of real service when shown to administrators, parents, or other teachers who visit her class and need a quick briefing on what is going on.

Overviews may be written in two or three different ways. One of the techniques is to make a list of the key subtopics that make up the general science topic being studied. These subtopics are usually given in the form of statements or understandings. They may even occur in the form of questions or problems as the children might visualize them.

For example, when studying the science topic of "Leaves" in the fourth or fifth grade, such an overview might be as follows:

1. What kinds of leaves are there and how do they differ?
2. What are the parts of a leaf?
3. What do leaves do for the rest of the plant?
4. Why and how do leaves change color in the fall?

A more elaborate but highly effective way of presenting an overview is to give it in written form, consisting of two or three paragraphs. The overview might begin by describing the importance of the science topic in our daily lives, for both child and adult. Then it might list the subtopics, and conclude by giving some general values and key desirable behaviors that the children will derive from the unit.

An example of this kind of overview, on the same topic of "Leaves," is as follows:

> Leaves are important to the daily life of both children and adults because they are one of the primary sources of food for all living things. Leaves and grass contain chlorophyll and can manufacture food, and from green leaves and grass we get all our food—either directly or indirectly. Hence, the study of leaves can be basic to the understanding of life and how it exists on earth. In addition, leaves give us one of the several signs of the change of seasons in many parts of the country.
>
> This unit hopes to teach (1) the kinds of leaves and how they differ from one another, (2) the parts of the leaf, including its external and internal structure, (3) the function of the leaf, with special emphasis on photosynthesis, and (4) the change in color of leaves in the fall.
>
> From the learning activities in this unit the children may gain a better understanding of leaves and their function, and an appreciation of the beauty and the way leaves are constructed. The children will develop further their ability to observe carefully and accurately, to listen intelligently, and to read science books for information. They will be asked to draw conclusions from what they have learned, and to apply these conclusions to life situations. Finally, they will learn how to express themselves more effectively, to participate more ably in class discussion, and to work democratically with their peers.

TEACHER'S OBJECTIVES

In general, the teacher has two main objectives: (1) to help the children learn basic science information, and (2) to develop desirable behaviors in the process. Both objectives are vital, and one is meaningless without the other. Consequently, definite provision must be made to incorporate both objectives into the unit. Otherwise the unit will fail to accomplish its purpose.

Some school systems develop only a scope and sequence chart, leaving the construction of units to the individual teacher. Other school systems appoint a science curriculum committee, which, under the guidance of a science supervisor or consultant, constructs a comprehensive set of units

for all the teachers. An analysis of science units, which have proven to be highly successful and which have enabled the teacher to achieve effective learning in the classroom, shows that they all have one factor in common. In all cases, the units contain an outline or list of the basic science information that the children are expected to learn while the units are in progress. And it seems that the more detailed the outline or list, the more successful are the units.

The preparation of an outline or list of concepts for inclusion in the unit helps the teacher in two ways. First, regardless of whether the unit is constructed by the teacher or by a committee, such an outline can be of great help as a guide when the learning activities are selected for the unit. Second, the outline serves as a check to make sure that the teacher will have the necessary science background for the topic being studied.

Giving the elementary teacher as much help as possible in acquiring the necessary science background is an important facet of any planned science program. An examination of current elementary science textbooks shows that approximately 33 percent of the content is in the area of biology, 33 percent is in the area of physics, 20 percent is in the area of geology, 8 percent is in the area of astronomy, and 6 percent is in the area of chemistry. (Meteorology is incorporated into the area of geology.) Thus to teach science effectively in the elementary school, the teacher should have a certain measure of knowledge and proficiency in these five areas. Unfortunately, this situation is not prevalent. It is generally agreed, and is verified by the findings of research, that most elementary school teachers have inadequate science backgrounds. Consequently, many of these teachers are reluctant to teach science.

Therefore, if teachers with an inadequate science background are given units that do not contain the basic science information, the teachers will be reluctant to use the units. This situation is easily understandable because all teachers realize that, unless they are at least moderately qualified to teach any subject, they may eventually be put into the embarrassing position of appearing inept before the children. A teacher does not mind saying "I don't know" occasionally to the children. But, when she has to say "I don't know" repeatedly, she soon stops teaching the particular topic or subject that places her in this awkward position. The teacher prefers to teach subjects in which she feels competent, comfortable, and secure.

If one of the objectives of science is to help the children understand and learn key concepts and conceptual schemes, it is imperative that the teacher be well informed about the science topics being studied. Otherwise the teacher will not be able to guide the children's learning profitably.

For the children to learn about the methods of heat travel, the teacher herself must be thoroughly familiar with the theory of molecular motion, the concept of heat, and the differences between conduction, convection, and radiation. She must know how these methods of heat travel are used in our daily lives and how they apply to the various phenomena in the children's environment.

When teaching about machines, the teacher must be familiar with the

concepts of force, work, mechanical advantage, and energy. She must know what machines are, how they help us, and their limitations. She must be aware that there are just six simple machines, and that all machines are made up of one or more of these simple machines. She must know the parts of each of these simple machines and their function. And she must have a working knowledge of the law of conservation of energy.

It seems fairly obvious, then, that a unit that spells out the science content to be learned can be of real value to the teacher. Yet many units fail to include a sufficiently detailed outline or list of the basic science information. This lack often exists in units that have been prepared by a curriculum committee for all the elementary teachers in a school system. This situation is unfortunate because any resulting reluctance or failure of the teachers to use the units will weaken or destroy the effectiveness of the planned science program.

Of course, many seemingly valid reasons can be offered for not including the basic science information in a unit. Perhaps a committee may feel that the teachers are already familiar with the science content. If the findings of research are to be believed, however, this assumption is usually not true. Perhaps the committee may feel that the teachers can obtain the information quickly and easily from the elementary science textbooks. Unfortunately, however, most textbooks distribute the science content over several grades, so that it is cumbersome for a teacher to locate all the concepts and put them together to achieve an overall view. Besides, most well-constructed units usually contain more science content and learning activities than can be found in the current elementary science textbooks.

Perhaps the units do not include the basic science information to discourage any tendency of the teachers to make learning of the "subject matter" the most important part of the unit. The term "teaching subject matter" has fallen into disrepute, especially in science, because science learning has too often consisted mainly of reading the textbook and then memorizing a mass of facts. As a result, there has been little or no development of desirable behaviors. This situation should not occur with a properly constructed unit. A good unit provides effective learning activities, which help the children learn worthwhile "subject matter" and at the same time develop the desirable behaviors. Thus, learning "subject matter" does not take place without the acquisition of desirable behaviors, and vice versa.

This condition is as it should be. For a long time, in an effort to dissuade teachers from just "teaching subject matter," the teachers were often admonished to remember that "We are not teaching science (or arithmetic or social studies, and so forth), but rather we are teaching children." Actually, the statement should be, "We are teaching *science* to *children;* we are teaching *social studies* to *children,*" and so forth. In this way we have equal emphasis upon both the learning of "subject matter" and the development of desirable behaviors by the children.

Another reason why an outline or list of basic science information is not included in units may be the feeling that such an outline or list will tend to make the unit too rigid. In fact, some persons do object to detailed

We are teaching *science* to *children.*

structuring of a unit because they feel this structuring deters exploration, investigation, and creativity from taking place freely in the classroom. The consensus, however, is that structuring helps rather than hinders. Only by careful planning and structuring by the teacher—and this factor is true especially for both the beginning teacher and the teacher with an inadequate science background—can effective on-going investigation, exploration, and learning take place in the classroom. Perhaps the objecting persons lose sight of the fact that the highly structured planning is primarily for the teacher, not for the children.

When a science curriculum committee constructs units for all the teachers in a school system, the members of the committee are usually competent in science. They have no difficulty in deciding which concepts are pertinent to the science topic and in organizing these concepts into a logical learning sequence. However, what about the teacher who is required to construct her own units? How can she select and organize the concepts, especially if she is unfamiliar with the science topic and the elementary science textbook does not contain enough science content for her needs?

One solution, found to be surprisingly effective, is for the teacher to consult a good junior high school textbook. Here she will find a complete presentation of the basic science information dealing with the topic she wishes to take up in class, expressed simply and clearly and arranged in a logical sequence. She can acquire the science background she needs and at the same time select those understandings she would like her pupils to learn. Naturally, consulting a high school textbook, or even a college text-

book, would be still better. However, when teachers have little or no science background, they are rather shy about using or reading books on more advanced levels. They also encounter increasing difficulty in selecting appropriate science understandings and adjusting them to the desired grade level. The junior high school textbook is usually adequate, and the science content is quite easy for the teacher to comprehend. Another source of help is the increasing number of reference books dealing with individual science topics at the elementary school level. These books present the basic science information simply and clearly, and they suggest many appropriate experiments and other learning activities.

After the teacher becomes familiar with the science content, the next step is the selection of science understandings that will be suitable for her grade level. If the teacher's school system has a planned science program, with scope and sequence, she will have some indication of what understandings to include. If there is no such program, the solution will have to be left to the judgment of the teacher. In either case she simplifies the wording of these understandings (without losing their scientific accuracy) to meet the vocabulary level of her class, and organizes them into what she thinks will be a logical sequence of learning. The latter is very important because one set of understandings will lead easily into another set of understandings, and in this way learning can take place quickly and efficiently.

When studying fire, for example, the children can begin one possible sequence by learning what fire is, then proceed to the factors necessary to produce fire, the concept of flame and smoke, the factors necessary to put out fires, different kinds of fire extinguishers, and finally appropriate safety rules for preventing or controlling fire.

The learning of basic science information by the children, then, is one of the teacher's two major objectives. The second major objective is the development of desirable behaviors. These behaviors include abilities and skills, scientific attitudes, appreciations, and interests. They also involve learning how to think critically and to solve problems. Such behaviors emerge from the learning activities that are conducted while the unit is in progress. The behaviors that emerge may be either immediate or long-range behaviors. Examples of these behaviors have already been described in Chapter 2, "Objectives of Elementary Science."

Although the basic science information is selected before the unit is written, it is difficult to select the desirable behaviors in advance. If the behaviors are selected first, the teacher is usually pressed to find the proper learning activity that will develop these behaviors. Learning activities call for specific behaviors. An oral report tends to develop the ability to speak effectively whereas a written report does not. An experiment helps to develop close and accurate observation much better than does reading. Each learning activity, as a rule, will call for the emergence of certain behaviors that are logical outcomes of the learning activity. The key to success is for the teacher to be fully aware of all the potentially desirable behaviors, and then to examine each learning activity closely and to work

for the development of those behaviors associated with that activity. If the teacher regularly uses the unit method of teaching and employs a wide variety of learning activities in her units, eventually she will have ample opportunity to develop any or all of the desirable behaviors she wants.

When constructing the unit, the teacher should be aware that, although there are many abilities and skills, there are much less scientific attitudes, and even fewer worthwhile appreciations and interests. Consequently, it would seem advisable to look for and select only those behaviors that would logically emerge from the learning activities. Otherwise they will seem farfetched and unrelated, and give the effect of padding the unit.

Finally, the behaviors should be worded clearly and specifically, and in terms that lend themselves to evaluation. Vague and indefinite behaviors are both meaningless and valueless because there is no possible way of evaluating them to see if they really did develop. It is also helpful if the behaviors are expressed in a consistent form. Some teachers prefer to express the behaviors in the form of questions. "Did the children go to reliable sources for evidence?" "Do they realize the need for a control experiment?" "Are they relating acquired facts into a meaningful whole?" "Are they able to apply what they have learned to a new situation?" Questions such as these lend themselves quite easily to evaluation by the teacher.

INITIATING ACTIVITIES

The purpose of initiating activities is to involve the children in the unit; these activities are the means whereby pupil interest and curiosity are aroused. In the process, questions and problems are raised that, when answered or solved, will help achieve the teacher's objectives. The main purpose of initiating activities is to raise questions or problems, the answers to which the children do not know but will find out as they proceed with the learning activities in the unit. Because the children do not know the answers, their curiosity is piqued and their interest in finding out the answers is aroused. Consequently, when the children participate in the learning activities for the unit, they learn basic science information that enables them to answer their questions or problems, and at the same time to develop desirable behaviors.

Usually a general or overall initiating activity is used to introduce or "initiate" the entire unit to the children. There are several ways of initiating the entire unit. Sometimes a previous unit will lead the children quite naturally into a new unit. If the class has just finished a study of magnets, for example, it will require very little effort to motivate the children for the study of electromagnets. Units can also be initiated by books and stories. Sometimes, merely the announcement of the next topic or problem may be sufficient to arouse pupil interest and problems.

Another way to initiate a unit is to set the stage for the unit. A good example is an attractive bulletin-board display, accompanied by thought-provoking questions. To initiate a unit on "Evaporation and Condensation," a teacher may plan to put on the bulletin board a series of pictures show-

A thought-provoking experiment can initiate a unit.

ing evaporation and condensation taking place. This display can include pictures of a puddle of water on a concrete sidewalk under the warm sun, sheets or towels drying on the clothesline, droplets of water on a bottle of soda pop or on the sides of a pitcher of lemonade, fogged-up windows, a person's breath visible on a cold, wintry day, and so on. Under the pictures can be questions such as—"How does the water get into the air?" "How does water come out of the air?" "How can we make water go into or come out of the air more quickly or more slowly?"

Another way to set the stage for a unit is to have a display of materials on a table with accompanying questions. Materials for display can include pictures, books, models, or specimens. When initiating a unit on leaves, it will be natural to have a variety of leaves on display, especially in the fall. Typical questions that can be asked would be—"Are these leaves alike?" "How are they different?" "How many parts does each leaf have?" "What do leaves do?" "Why do leaves change color in the fall?"

A thought-provoking experiment or demonstration is an excellent way to initiate a unit. A teacher can initiate a unit on "Methods of Heat Travel" by simply placing a spoon in a cup of hot water. Pupil interest and curiosity will be raised about why the part of the spoon that is out of the water also becomes hot.

Even a thought-provoking discussion can initiate a unit. In temperate climates most children are quite familiar with the effects caused by static electricity, especially on a cold, dry day. The teacher can initiate a unit on such a day by first asking the children to describe personal experiences

with static electricity and then leading into an on-going discussion about the characteristics of and reasons for this phenomenon.

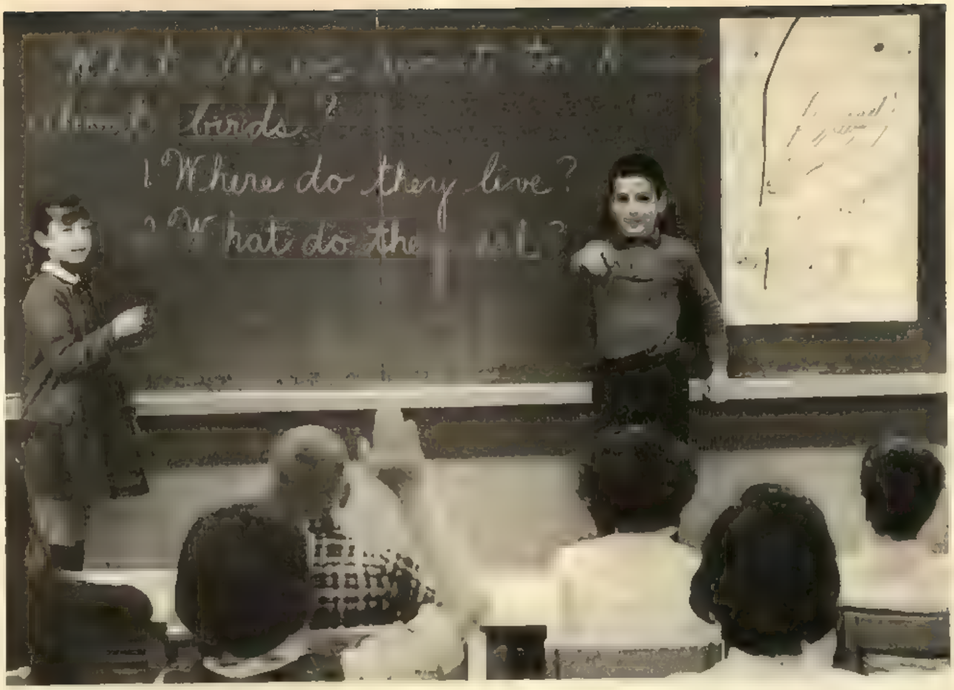
It may well be mentioned again that the initiating activity should raise questions and problems that the children cannot answer immediately but will be able to answer later, after they have performed or participated in the learning activities that will supply the information to answer the questions or problems. If the initiating activity selected does not raise questions or problems, it should be discarded and a new one substituted.

There are many who believe that one good general or overall initiating activity is sufficient to sustain pupil interest and motivation for the entire unit. They feel that the one activity will raise enough questions and problems to ensure the learning of all the science understandings in the unit. On the other hand, there are others who think that additional initiating activities are necessary as the unit progresses. These additional activities may be necessary, especially when a unit extends over two, three, or even more weeks. Interest and motivation may flag over a period of time for even the most enthusiastic children.

Also, when teachers organize the basic science information into outline form for easier use in the unit, the science understandings in the outline seem to arrange themselves into groups of related understandings that make natural headings or subtopics for the main science topic. Although these headings or subtopics are all part of the main topic, they differ in science content sufficiently among themselves to warrant having their own initiating activities. Thus, a unit may need enough initiating activities to raise pupil questions or problems involving all the science understandings in the outline of basic science information. Usually one initiating activity is needed for each group of related science understandings that constitutes a heading or subtopic in the outline of basic science information. Thus each initiating activity leads to learning activities from which the children will learn a group of related understandings.

The need for subsequent initiating activities while the unit is in progress can be illustrated by the topic "Magnets." The understandings in an outline of basic science information may easily fall into headings or subtopics such as: (1) "What Magnets Are and What They Do," (2) "The Law of Magnetic Attraction," (3) "What Materials the Force of a Magnet Will Pass Through," (4) "How Magnets Are Made," and so forth. A good general initiating activity should prepare the children for study of magnets in general. The same general initiating activity may even be used to initiate learning activities for the first heading or subtopic, "What Magnets Are and What They Do." However, it seems obvious that a new initiating activity is needed for the second heading, and for the third and fourth headings as well.

Thus, additional initiating activities—other than the general or overall initiating activity—may be used at various intervals as the unit progresses. The most effective activities are thought-provoking experiments and demonstrations, questions or series of questions, and discussions. Occasionally, one or more frames of a filmstrip can be used as an initiating activity. Often



Listing pupil objectives.

the general or overall activity can also be used as the initiating activity for the first heading or subtopic of the outline of basic science information.

Films, field trips, and speakers should rarely be used as initiating activities. The purpose of initiating activities is to raise questions or problems, the answers to which the children do not know, which then necessitates special learning activities to find the answers. Films, field trips, and speakers as a rule not only raise questions, but also usually provide the answers to the questions immediately afterward. This procedure defeats the purpose of the initiating activity.

Similarly, because the initiating activity raises questions instead of giving answers, the initiating activity is almost never used as the first learning activity. The purpose of the learning activity is to find out information whereas the initiating activity is designed only to raise questions. However, the initiating activity can be used to advantage as an evaluative technique later in the unit. If the children have really learned the science understandings in the subsequent learning activities, they should now be able to answer the questions or solve the problems raised by the initiating activity.

The selection of good initiating activities is perhaps the most difficult phase of unit construction. Very often, many pupils are able to explain what were intended to be thought-provoking experiments or demonstrations. Thus, the initiating activities have not fulfilled their purpose and are valueless. The teacher should not become discouraged, but she must discard the unsuccessful initiating activities and continue her search for new and better ones.

PUPIL OBJECTIVES

Units often include pupil objectives. These objectives are the anticipated pupil questions or problems that will emerge from the initiating activities. The questions and problems are stated as the children might raise them in the children's own vocabulary. Pupil objectives thus also remind us that the children's aims may be quite different from those of the teacher. The teacher may want the children to learn about heat expansion. The children, however, will want to know why cracks are intentionally put into concrete sidewalks. The teacher is interested in electrical circuits; the children want to learn how to connect a dry cell, wires, and a porcelain socket containing a bulb so that the bulb will light up. The teacher is interested in the laws governing vibrating strings; the children want to know what can be done to make the musical note from a violin or guitar higher or lower. The teacher is primarily concerned with the learning of basic science information and the development of desirable behaviors. The children want to know "why," "what," "how," "when," "what will happen if," and so forth.

If the initiating activities are properly selected, the pupil objectives will emerge easily. However, because the pupil questions and problems in the planned unit are anticipated, if the children should fail to raise them, the teacher may ask them instead. Actually, the children often raise better or more questions and problems than those anticipated by the teacher. The wise teacher incorporates these questions and problems into the unit.

LEARNING ACTIVITIES

Learning activities are the means by which the children learn basic science information and develop desirable behaviors. In the process, the children acquire understandings that enable them to answer the questions or problems raised by the initiating activities. The teacher uses a wide variety of learning activities in the unit to accomplish this purpose. All the techniques and activities suggested in Chapter 4, "Methods of Teaching Science," are utilized. These include experiments, demonstrations, observation, reading and study, discussion, oral and written reports, films, filmstrips, speakers, models, charts, posters, individual and group planning, and so forth.

Many teachers have a tendency to use many more learning activities than are necessary to ensure satisfactory learning. This overpreparation tends to prolong the unit unnecessarily, slow down learning, and dull pupil interest. The experienced teacher employs her learning activities wisely and economically, especially when teaching for science understandings. She realizes that sometimes one activity is enough for an understanding to be learned. Occasionally one good learning activity will suffice to produce the learning of more than one understanding, especially if the understandings are simple or are related to each other. Other times, when an understanding is difficult or abstract, more than one activity may be necessary to obtain adequate learning. Slow learners usually learn better when more than one activity is used.

The grade level may also influence the number of learning activities needed. In the lower grades, where the children's attention span is small and their ability to think abstractly is not well developed, more than one activity is often necessary to obtain satisfactory learning of an understanding. However, in the upper grades one well-chosen activity is usually sufficient.

In all cases the best procedure is for the teacher to use as many—but *only* as many—activities as are necessary to ensure satisfactory learning. And if the teacher finds that there is a surplus of activities, they can always be used as additional activities for slow and fast learners.

MATERIALS, BIBLIOGRAPHY, NEW SCIENCE VOCABULARY

When planning a unit, the teacher should list all the materials that will be needed for the learning activities. This list includes supplies, equipment, textbooks, reference materials, films, and filmstrips. In this way the teacher can begin to accumulate the necessary materials and have them ready and available as the activities require them.

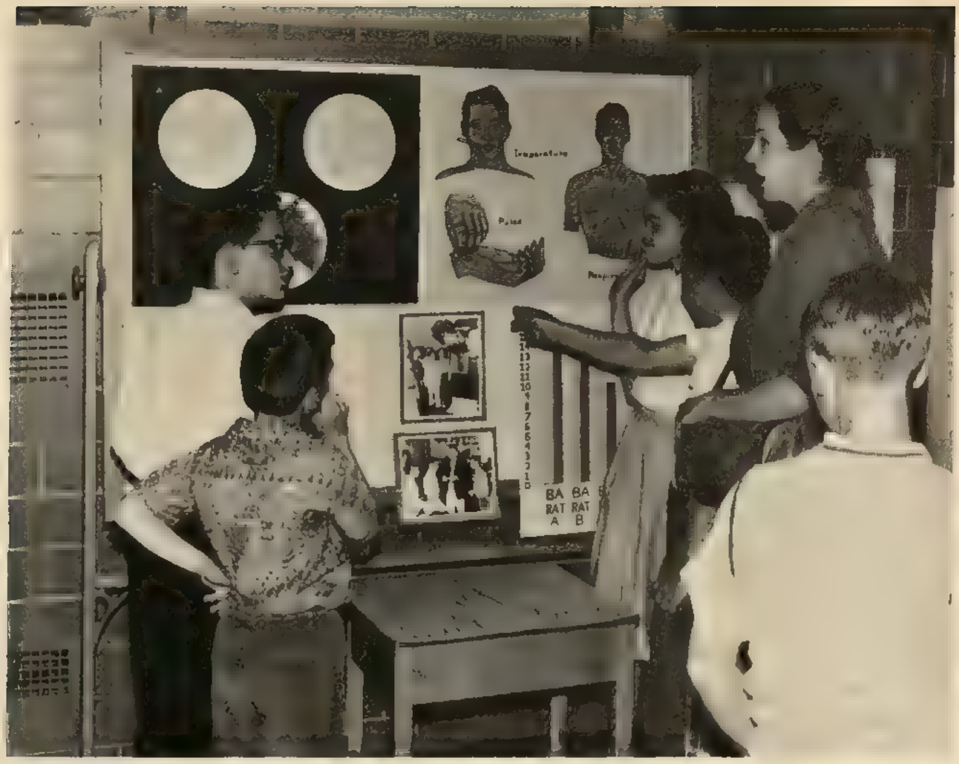
Most units contain a bibliography of the textbooks and other reference materials that will be used during the unit. This bibliography includes materials for both the children and the teacher. The pupil list contains those references that the children will use to answer questions, solve problems, learn how to do an experiment, check conclusions, and find additional information for reports, and so forth. Where possible, it is wise to include duplicate references on the same topic, but on different grade (reading) levels. Thus, there will be available reading materials for slow and rapid learners. The teacher list should contain those references that either describe in detail an experiment or demonstration that she plans to use or those that give her additional information about the topic.

For clarity, the pupil and teacher references should be listed separately. Each reference should include the title, author(s), publisher, place and date of publication, and grade level (if it is part of an elementary science textbook series). Films and filmstrips should be included in the bibliography, usually under a separate listing. Besides listing the title and the producer, it may be helpful to add such information as the running time, whether it is in black and white or color, and so forth.

With the development of ideas and understandings, the children regularly will encounter new words and terms. This new vocabulary must be thoroughly explained and understood for maximum learning to take place. Many teachers find it expedient to include a vocabulary list of the new science terms that will be learned and used during the unit; this list reminds the teacher to give full attention to the learning of the terms when they appear for the first time.

CULMINATING ACTIVITIES

A culminating activity is an activity that concludes the unit. It should be a logical part of the unit and a natural outgrowth of the work in the unit. It should appear when the objectives of the unit have been achieved. The



A culminating activity can be a display of exhibits.

culminating activity helps summarize the learnings and brings the high points of the unit into focus.

Culminating activities can be many things. They can be films, filmstrips, field trips, or speakers. They can be exhibits, science fairs, news letters, or reports. They can even be discussions, programs, assemblies, or dramatizations. However, the teacher should always keep in mind that culminating activities are primarily for the benefit of the children, even though others may profit from them as well.

Certain precautions should be noted about the use of culminating activities. They should not try to summarize every science understanding in the unit because this procedure would make the activity much too long, with the resulting loss of interest and educational value. Not every unit needs a culminating activity. Some units do not lend themselves well to such activity, and to have one arbitrarily would make the activity highly contrived and artificial. Also, sometimes a culminating activity can actually hinder the children from continuing quite naturally to another unit. Finally, tests and other evaluative techniques are not culminating activities and should not be used as such.

EVALUATION

It seems natural that the teacher should plan evaluation when constructing the unit. It is much easier to think about how to evaluate pupil

progress and growth while every phase of the unit is fresh in the teacher's mind. Evaluation should be continuous while the unit is in progress. The teacher must determine how well the children have learned the basic science information. Evaluation must be made for the development of desirable behaviors. The children themselves can—and should—participate in much of the evaluation. They can evaluate their work, their daily progress, and their learnings and behaviors as well. The various techniques for evaluation that can be used by both teacher and children are described in Chapter 8, "Evaluation of Science Learning in the Classroom."

WORK SHEETS

When constructing the unit, the teacher must give much consideration to how the work in the unit will proceed. Once the unit is in progress all the components of the unit must be coordinated and utilized to achieve maximum learning. Thus, the basic science information, the initiating activities, the pupil objectives, the learning activities, and the materials should be combined into functional learning situations. At the same time provision must be made for evaluation of the work that is being done. Consequently, the working period is the vital part of the unit and, as such, must be thoroughly integrated. For in the working period lies the success—or failure—of the unit.

There are several forms in which the working period can be presented. Of these forms, two are most commonly used, both using work sheets. One form describes the working period in outline form, giving an on-going description of how the learning will be developed. The other form, which seems to be more popular, uses parallel columns. The number of columns as well as the order in which the columns are listed may vary. Each column contains a phase of the working period. For example, one column may contain the teacher's objectives; a second column, the pupil objectives; a third column, the learning activities; a fourth column, the materials needed; and a fifth column, provision for evaluation. The advantage of arranging the working period by columns is that everything can be laid out so that the teacher can immediately see the direction in which the work is going and the progress that is being made. By using adequate spacing, the teacher's objectives can be placed beside corresponding pupil objectives, learning activities, materials, and evaluation techniques. Thus, the teacher has a horizontal row of related components, all clearly delineated. To set up the work in columns may involve a little more time and effort, but the result is certainly worthwhile.

Constructing Specific Units

CONSTRUCTION of a unit entails careful planning and preparation by the teacher, but the rewards are great, namely, the best possible learning. When units bog down or collapse, the failure is generally because of a lack of adequate planning and preparation. A very hastily prepared or poorly

constructed unit will create "dead spots" in a learning situation, which cannot ordinarily be remedied by the teacher's ingenuity or ability to think quickly. When this situation occurs often—and sometimes one unfortunate experience suffices—the teacher is likely to reject all unit construction as a "waste of valuable time," and thus discards what is generally considered a most valuable and effective teaching technique.

Initial attempts to construct units are often slow and time-consuming, as are other valid teaching techniques when planned and presented for the first time. The teacher may spend a lot of time in finding the best sources for collecting the basic science information and the learning activities, and an equal amount of effort in coordinating all the unit components into an effective working plan. However, once the pattern becomes familiar, the time and effort involved lessens considerably, and the results become increasingly satisfying and rewarding.

When looking for guides or models for constructing units, the teacher may become confused or bewildered by what seems to be a large variety of units in the literature. Curriculum experts, all vitally interested in good teaching and learning, have proposed or identified different kinds of units. As a result we now have experience units, process units, source or resource units, problem units, activity units, center of interest units, topical units, survey units, and so forth. To add to the confusion, the term *unit* has become so popular that teachers use it very loosely to describe almost any kind of teaching-learning situation. Some teachers have even used the term when referring to any project in progress or to a chapter in the textbook.

All the different classification and identification of units can confuse the teacher, and can often discourage her from using the unit method in her classroom. However, there is a strong feeling today that, although there may be different names for the unit, there is definite agreement and unity about the function of the unit. Accordingly, the chief criterion for a unit is that it should provide good interaction between the subject matter and the learning activities to produce changed behaviors in the child.

Before suggesting one of the many outlines that can be used to plan and construct units, it may be helpful to point out certain pitfalls that the teacher should avoid. First, teachers who begin constructing their units by selecting the learning activities first, without considering exactly what basic science information is involved, almost invariably encounter difficulties. Not only do they find themselves without a logical sequence of learning, but also they are likely to be embarrassed during the unit when they discover that they cannot explain the science principles associated with the activity. It seems as if the more logical way of beginning would be first to select the basic science information to be learned, and then to look for the best possible learning activities that will result in the learning of this information and in the process develop desirable behaviors.

A parallel situation occurs when teachers state their behavioral objectives first. They soon discover that they have difficulty in finding the appropriate learning activities that will teach these behaviors. And, if they do locate suitable activities, these activities may not teach the desired basic

The science unit must provide for a wide variety of activities.

science information. The situation will be complicated further if the behaviors are expressed in broad, flowery terms, rather than in specific terms, so that the behaviors do not lend themselves easily to proper teaching, learning, and evaluation. To avoid this pitfall, the teacher may find it helpful first to select the basic science information and learning activities, as suggested previously. Then the teacher should look well at the learning activities because the activities will suggest the most appropriate and desirable behaviors to be developed. For example, it is obvious that activities with experiments will develop different behaviors from activities with reading and discussion. If the teacher is aware of what behaviors the children should develop, the activities will provide clues as to which behaviors will best emerge from the particular activities used.

Another pitfall to be avoided, especially by the beginning teacher, is concerned with the use or development of resource units. Resource units, sometimes called source units as well, usually consist of a collection of learning activities, materials, bibliography, and even evaluative materials, which the teacher may use or organize into a unit. When such resource units also contain the appropriate basic science information to be learned, the teacher has comparatively little trouble in organizing the materials she needs into an effective unit. However, many resource units do not include science information. When using such units the teacher should first learn the science content involved. This knowledge will prevent future difficulty as well as possible embarrassment or confusion. When constructing resource units to be used by the teachers in a school system, the working group of

teachers would thus do well to include the appropriate science understandings. Otherwise the teachers, not knowing or understanding the concepts underlying the activities, will be reluctant to use the activities, even if they are excellent.

Furthermore, a resource unit usually contains a very extensive collection of activities—more than are needed for the learning situations. At no time does the resource unit imply that all the activities are to be used. The idea is to have enough activities available so that the teacher can select the activity that is most suitable. Yet many teachers, particularly beginning teachers, try to incorporate all of the activities when teaching a science topic. As a result the unit may become so long and take so much time that the teacher becomes both frustrated and bitter. She begins to feel as if she could have accomplished as much in half the time, and without the additional time and effort involved in working with units. Consequently, the teacher often gives up an excellent teaching technique when all she needed was information about how to use the resource unit properly.

A last word of caution is directed to beginning teachers who have read or been told that a good teacher does not have to plan the unit carefully and rather should try to build from questions, conversations, arguments, or other sporadic incidents that occur in the classroom. This method is not as simple as it may sound. Definite readiness is required for this kind of emerging lesson or unit. First, the teacher must have a competent science background so that she is familiar with the topic under discussion. Then the teacher must be acquainted with a wide variety of experiments, demonstrations, and other learning activities suitable for teaching the understandings associated with the topic. Finally, the appropriate supplies, equipment, references, and other materials must be easily or already available. Once the teacher has this background of science knowledge, activities, and materials, she is in an excellent position to convert questions and incidents into worthwhile learning situations. The same readiness is also necessary for experienced teachers. A science lesson or unit can emerge from incidents in the classroom only when the teacher has the necessary knowledge and tools to take advantage of the situation.

A teacher, then, must acquire the necessary background, materials, and experience before she is ready to use a resource unit successfully or is able to develop a unit on the basis of incidents that arise in the classroom. Until that time, the teacher might do well to use a structured unit with a definite pattern of organization, as described in this chapter.

Outline for Constructing a Unit

THE FOLLOWING outline for a unit is an example of only one of many outlines that can be used. And because it is just one example, teachers need not feel obligated to use this kind, or even to follow it exactly. There are others available that achieve the same purpose and objectives. This outline serves as a guide, and illustrates the main points of which to be aware

when constructing units. Actual illustrations of units that can be prepared according to this outline are given in Chapter 6.

I. TITLE

II. OVERVIEW

The purpose of the overview is to describe briefly the nature and scope of the unit. One method of presenting the overview is to write it in two or three short paragraphs, giving the importance of the science topic in our daily lives, the key science concepts to be learned, and the desirable behaviors to be developed. The overview should be written as if it were addressed to administrators, fellow teachers, or parents. An alternate method would be to have a table of contents. The table would consist of either key concepts or pupil questions and problems.

To write the overview the teacher must first have a reasonably clear picture of the learning activities to be used, the basic science information to be learned, and the desirable behaviors to be developed. Consequently, it would be helpful not to write the overview first, but rather to wait until the rest of the unit has been developed.

III. TEACHER'S OBJECTIVES (SCIENCE UNDERSTANDINGS)

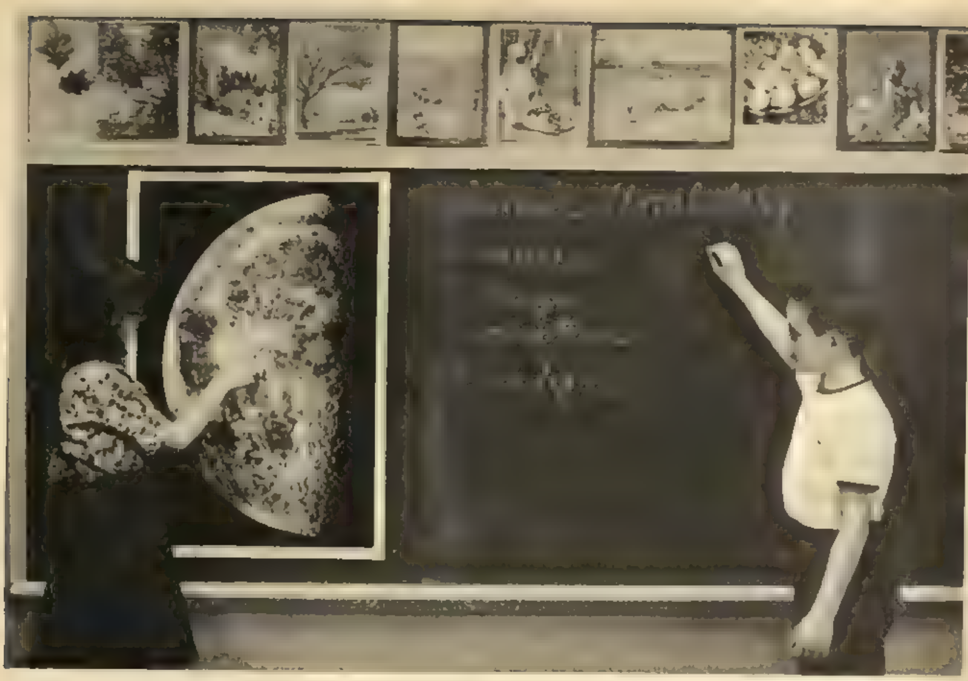
As stated before, there are two main teacher's objectives: (1) to help the children learn basic science information, and (2) in the process to develop desirable behaviors. Both of these objectives will appear in the work sheets. However, it has often been found helpful to the teacher to have the basic science information also appear in the first part of the unit. The purpose is to enable the teacher quickly and easily to refresh her knowledge from year to year of the science understandings pertaining to the topic being studied. It also makes it possible for the teacher to get a complete picture. In the work sheets the understandings appear throughout a number of pages. But, when presented as a complete body of knowledge in the first part of the unit, the teacher can see all the interrelationships between the various concepts.

Teachers may devise any form they like for listing the basic science information in the unit. One highly successful method is to present the science understandings in outline form, with subtopics or headings. An outline also helps the teacher to check the understandings the children already know, after giving a pretest. The outline should consist of complete sentences, not fragmentary words or phrases.

IV. GENERAL OR OVERALL INITIATING ACTIVITY

This activity "initiates" or sets the stage for the unit. It may be an attractive bulletin-board display, a display of materials on a table, or a thought-provoking experiment, demonstration, question, or discussion. The purpose of the activity is to raise pupil interest and questions or problems about the science topic being studied. Many teachers, when planning the unit, even anticipate some of the major pupil questions or problems that will arise.

Sometimes just the announcement of the next science topic will arouse



Listing new science vocabulary.

pupil interest, questions, and problems. And sometimes one unit will lead so naturally into a second unit that an initiating activity is not necessary.

When a general or overall initiating activity is included, the teacher should describe the activity briefly in a paragraph or two to show how she plans to set the stage or initiate the unit. If anticipated pupil questions or problems are to be included, they should follow immediately afterward.

V. NEW SCIENCE VOCABULARY

The new science terms that will be learned during the unit may be included at this time. The vocabulary may be placed where the teacher prefers: immediately after the list of basic science information, after the general initiating activity, or even after the bibliography. Some teachers write it as a glossary, defining the terms, rather than as a straight vocabulary list.

VI. BIBLIOGRAPHY (AND CODE)

The bibliography is the list of pupil and teacher references that will be used during the unit. Most references, if not all, will also appear in the work sheets. When including pupil references, the teacher would be wise to make provision for different levels of reading ability. Most teachers, for the sake of clarity, list the pupil and the teacher references separately. They also have a separate listing for films and filmstrips.

Some teachers find it helpful to assign a code number or letter to each reference. This procedure tremendously reduces detail when the references are given in the work sheets. Actually, the references appear twice in the

unit for this reason. The first time, in the bibliography, each reference is given completely, with the title, author(s), publisher, and date and place of publication. By assigning a code number or letter to each reference, when references are required in the work sheets, only the code number and the page numbers have to be written down.

Many teachers also prefer to place a *P* or *T* beside the code number or letter in the work sheets to distinguish between pupil and teacher references, respectively. Some teachers even insert one asterisk to denote a reference for slow learners, and two asterisks (or a dagger) for fast learners. This procedure is optional, of course.

VII. WORK SHEETS

The work sheets indicate how the teacher anticipates the work will proceed as the unit develops. These sheets may contain pupil and teacher objectives, any subsequent initiating activities, learning activities, materials, desirable behaviors to be developed, and even some indication of how the teacher hopes to evaluate the work in the unit.

One method of constructing work sheets is to use parallel columns. Teachers vary in the number of columns they use and in the order in which the columns appear in the work sheets. One arrangement uses six columns, as follows:

Initiating Activities and Pupil Objectives	Basic Science Information	Learning Activities	Supplies and Equipment	Texts and References	Evaluation

A. Column 1: Initiating activities and pupil objectives · The "Initiating Activities and Pupil Objectives" column contains any subsequent initiating activities needed to raise pupil questions or problems. There should be enough initiating activities to assure the teacher that questions or problems will be raised about every subtopic or heading in the outline of basic science information on the main topic. Usually one activity is needed for each subtopic or heading of the outline. Thus each initiating activity leads to the study, and learning, of the science understandings in each subtopic or heading. Sometimes more than one activity may be considered necessary for one subtopic or heading. Conversely, one activity can be used for two or more subtopics or headings. And occasionally the general or overall initiating activity can also serve as the initiating activity for the first subtopic or heading. Each initiating activity should be described briefly but adequately, using one or more sentences as needed.

The column also contains the pupil objectives—namely, the questions

and problems that arise from the initiating activities. These questions can be placed beside the appropriate science understandings, which appear in the second column. Only logically anticipated or real questions and problems should be listed. Some teachers feel that they must have a pupil objective for each science understanding; it is not necessary, however.

B. Column 2: Basic science information · Column 2 contains the science understandings, which usually appear in outline form with subtopics or headings. Teachers often begin the outline in this column a short distance below the initiating activity in the previous column. They organize the material in this way to remind themselves that the initiating activity should be carried out first.

C. Column 3: Learning activities · Learning activities include experiments, demonstrations, observation, reading and study, discussion, oral and written reports, films, filmstrips, field trips, speakers, individual and group planning, and so forth. These activities are the means by which the children learn basic science information that enables them to answer the questions or problems raised by the initiating activities, and in the process to develop desirable behaviors.

The teacher should almost never use an initiating activity as the first learning activity as well because the initiating activity raises questions rather than gives answers. It is the purpose of the learning activities to answer the questions raised by the initiating activity. The initiating activity, however, can be used as an evaluation technique later in the unit. If the children have really learned the science understandings, they should now be able to answer the questions or solve the problem raised by the initiating activity.

The learning activities need not be described in detail in the column. A sentence, or even a phrase, is usually adequate. It should be just long enough for the teacher to recognize the activity now as well as in the future. If the activity is an experiment or demonstration and the teacher would like to review the entire procedure, she can look at the reference for the experiment or demonstration, located in the column for textbooks and references.

The learning activity should be located beside the corresponding science understanding or understandings. Sometimes one activity is sufficient to produce satisfactory learning of an understanding and/or development of a desirable behavior. Sometimes one activity is sufficient to produce learning of more than one understanding. Often, however, more than one activity is needed to produce satisfactory learning of one understanding. In this case the activities should be listed in logical sequence of presentation. Also, when this happens, the spacing in the column for basic science information must be adjusted. Adequate blank space should be left between understandings so that the teacher can recognize immediately that all the learning activities apply to only one understanding.

The culminating activity appears in this column, usually on the last work

sheet if there is only one culminating activity. If there are several short culminating activities in the unit, they should be located at appropriate positions in the column and labeled "Culminating Activity" before the description of each activity.

D. Column 4: Supplies and equipment · Column 4 lists all the special materials the teacher and children will need to conduct an experiment, demonstration, or other working activity. It also contains any materials that might be used for the initiating activities or the culminating activity.

The materials should be listed beside the corresponding learning activity that will require these materials. If the list of materials needed for a particular learning activity is quite long, adequate blank space should be left in the column for the learning activities so that the teacher can see immediately which materials are needed for which activity. Thus, by allowing adequate space in each column, the teacher should be able to identify quickly which materials belong to which activity for which understanding, and for which pupil objective.

E. Column 5: Texts and references · Column 5 contains all the textbooks and references used for reading, discussion, reports, locating and doing experiments, checking observations and conclusions, and so forth. It also includes films and filmstrips as well as any references that might be needed for the initiating activities or the culminating activity. As already mentioned in the section on bibliography, the references can appear as code numbers or letters. Placement of a *P* or *T* beside the code number or letter will help distinguish between pupil and teacher references.

The textbooks and references should appear beside the corresponding learning activity. Incidentally, the nature of the activity will determine whether it is necessary to list supplies and equipment, textbooks and references, or both. Usually an activity involving reading does not require supplies and equipment. However, an experiment or demonstration may require both a list of materials and a reference for the teacher or pupils.

F. Column 6: Evaluation · Column 6 contains the desirable behaviors that the children will develop from the learning activities, and also the various methods that will be used to determine whether learning of the basic science information has taken place.

The behaviors can be stated as phrases or as questions. They should be listed beside the corresponding learning activities. At the same time the teacher should remember that it is not necessary to include all kinds of behaviors just to have them in the unit because they are good. Only those behaviors that will really develop from the learning activities should be included.

The methods for determining whether learning has taken place should appear either beside the corresponding learning activities or at the end of a set of understandings. Some teachers just indicate briefly what technique will be used, such as oral or written report, question and answer, short

objective test, and so forth. Other teachers prefer to describe in greater detail how they will evaluate to find out if learning and changed behaviors have occurred.

This column can also be used to check whether the children can now answer the questions, or solve the problems, raised by the initiating activities.

G. Additional suggestions · Allow sufficient space when filling in the columns of the work sheets. This space is necessary if the teacher is to see at a glance which pupil objective belongs to which understanding, which understanding requires which learning activity, and which activity calls for which materials or references or desirable behavior or evaluation technique. In other words, all the related materials in the six columns should be easily identified by being side by side in the columns. Sufficient space also enables the teacher to incorporate additions or make changes in the unit and work sheets without having to rewrite the unit or work sheets each year.

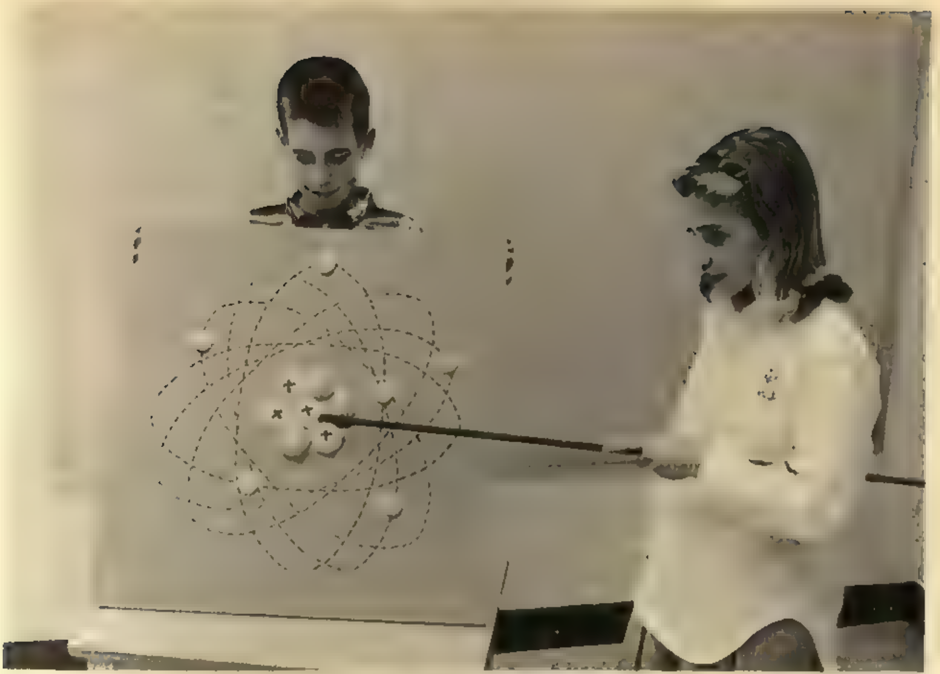
All of the columns do not have to be the same width. Obviously, the columns for the basic science information and the learning activities need more space than the others. However, to compensate for this extra width, the columns for the supplies and equipment and for the textbooks and references can be much narrower.

Finally, it will help the teacher if the six columns are spread out over two sheets of paper. This spacing makes it easy to incorporate the sheets into a folder or a loose-leaf notebook. The work sheets will then look like the pages of a book, with the first two or three columns on the left-hand page and the remaining columns on the right-hand page.

VIII. DAILY PLANS

Daily planning is an integral part of teaching and requires time and effort. The unit can be quite helpful to the teacher in this way because the work sheets of the unit will function nicely as daily lesson plans as well. The teacher merely has to anticipate how much can or should be taken up in one day, then draw a dotted line all the way across the sheets, indicating a break or stopping point. This section of the work sheets now has practically everything that a good daily lesson should have. The initiating activity and pupil questions or problems are a good beginning for the lesson. The basic science information, learning activities, and list of materials and references constitute the body of the lesson. The end of the lesson contains the evaluation of learning and desired behaviors. Thus, by using work sheets, the teacher has a unit plan and a daily lesson plan at the same time.

One method of determining a day's work is to examine the learning activities. An estimate of the time these activities are likely to need may help determine how many activities can be taken up in the time allotted for teaching science. Another method is to examine the list of science understandings to be learned. Some subtopics or headings contain a small number of understandings that can be easily learned in one day and, therefore, constitute a natural break. This natural division occurs often in units



Providing additional activities for fast learners.

designed for the lower elementary grades. However, where the subtopics or headings contain a large number of understandings, careful scrutiny should disclose that these understandings can be subdivided into smaller, related sets or groups of understandings. These smaller sets or groups of related understandings can also constitute a day's work. This situation is more likely to occur with units designed for the upper elementary grades.

The beginning teacher should constantly remember that this determination is only an estimate of what will constitute a day's work. If, in actual practice the lesson is too long or too short, the teacher can merely erase the original dotted line and put in new lines at the appropriate places.

IX. PROVISION FOR SLOW AND FAST LEARNERS

Many teachers have found it helpful to include at the end of a unit a list of extra activities that can be used for slow and rapid learners. The need for such activities in a teaching-learning situation is obvious. Usually two separate lists are made, one for each kind of learner. Each list has two columns. In one column the activity is described briefly. The other column contains the necessary materials and/or references for the corresponding activity.

Practical Suggestions for Constructing a Unit

BEFORE constructing a unit the teacher must acquire a general background of the basic science information involved in the topic to be studied. This

background may be obtained by going through all the books in one or more elementary science textbook series, and also consulting a good junior high school textbook to get a more complete picture. The teacher might be wise to write down the page numbers and books where the information is located for future use as bibliography and references.

The teacher will find it immeasurably helpful first to make a rough draft of the unit. First select all those understandings suitable for your grade level. Some of these understandings may have to be reworded so that they are at the proper vocabulary level. Then make an outline or list of these understandings, arranged in a logical sequence, with subtopics and headings.

Beside the understandings write down the corresponding learning activities you have selected to help the children learn the understandings. Use only as many activities as you think necessary to produce satisfactory learning. Save any surplus activities for additional activities for your slow and fast learners.

Examine your list of understandings and learning activities. Use this list to determine what supplies, equipment, textbooks, and references you will need.

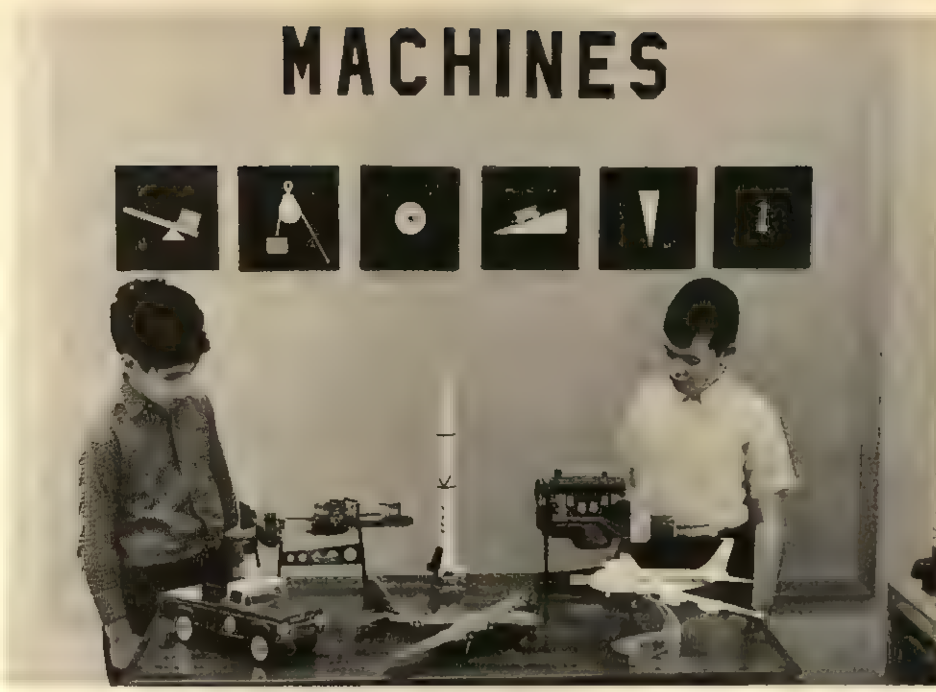
Select the general or overall initiating activity that will begin the unit by focusing pupil interest or raising questions and problems. Then select as many subsequent initiating activities as you think necessary to raise pupil questions or problems for all the understandings listed.

Now examine the learning activities closely. From each select the key desirable behaviors you think should develop as a result of the activity. Review the science understandings, learning activities, and desirable behaviors again to decide tentatively what evaluation techniques may be used to determine if learning has taken place. Also, this is the time to think of a good culminating activity.

Next, write the overview, make a list of new science vocabulary, and draw up a bibliography. Then make a rough copy of the work sheets so that you can allow for sufficient and proper spacing in the final copy.

CHAPTER

6



Sample Science Units

It is often said that "a picture is worth a thousand words." This saying is particularly true for unit construction. No matter how precise and explicit a set of instructions may be, as given in Chapter 5, "Planning for Science in the Classroom," nothing helps as much as one or two representative models of units to clarify the directions and to illustrate the techniques involved in unit construction.

Accordingly, the three structured science units that follow are presented as examples. These units were written as a regular assignment by students in the author's course on methods of teaching science in the elementary school.

Structured units were selected because they are the most detailed of all the different kinds of units currently used. Such detail is necessary for both the beginning teacher and the teacher whose science background needs strengthening, because these teachers are not very familiar with the basic science information, the learning activities, and the objectives of elementary science. It is not necessary to follow the format of these sample units rigidly; the units can be modified to suit the individual preferences and

needs of the teacher. However, the basic rationale for setting up this kind of unit should not be overly distorted.

To illustrate how these units may be modified, the unit "Electromagnets" for grade 6 contains a different kind of overview, and the column on evaluation (in the work sheets) has been eliminated. Such changes are often made when a school or school system is in the process of developing a comprehensive science program, including structured units for the teachers. Sometimes the group that is working on units will prefer to list all the desirable behaviors at the beginning of the course of study for each grade. This procedure eliminates the need for a special column on evaluation, and the group now does not have to repeat the same desirable behaviors in each unit for each grade. The change in the overview is made for the same reason. Many times the listing of the basic science information at the beginning of the unit is omitted.

As teachers become more experienced in the teaching of science and develop a stronger science background, they invariably make a transition from structured units to resource units. The content and format of resource units vary, and also differ greatly from structured units. The initiating activities and pupil objectives are usually much briefer. Often the pupil objectives are completely eliminated. The basic science information is not as detailed, and only key concepts or topics are listed. However, there is a tendency to include a wide variety of learning activities for each concept so that the teacher will have an opportunity to select those activities most appropriate for use as the learning situation develops. As a rule the column on evaluation, which contains the desirable behaviors, is omitted.

Because of such modifications and omissions, the impression may arise that resource units are less time-consuming to construct than structured units. This impression is false. The same high degree of planning is required to ensure that successful teaching and learning take place in the classroom. Actually, as teachers become more adept in teaching science, the time and effort they spend in planning increases accordingly.

For the sake of convenience in ordering books, the references in the units have been updated to reflect the current names and addresses of the publishers; Row, Peterson has merged with Harper, for instance, so Row, Peterson titles are listed as Harper books.

The dotted lines across the work sheets indicate the end of each day's activities.

CARE OF PLANTS AND WAYS OF GROWING THEM

A Unit for Grade 2

SUBMITTED BY: Margaret Miller
Northwestern University

OVERVIEW

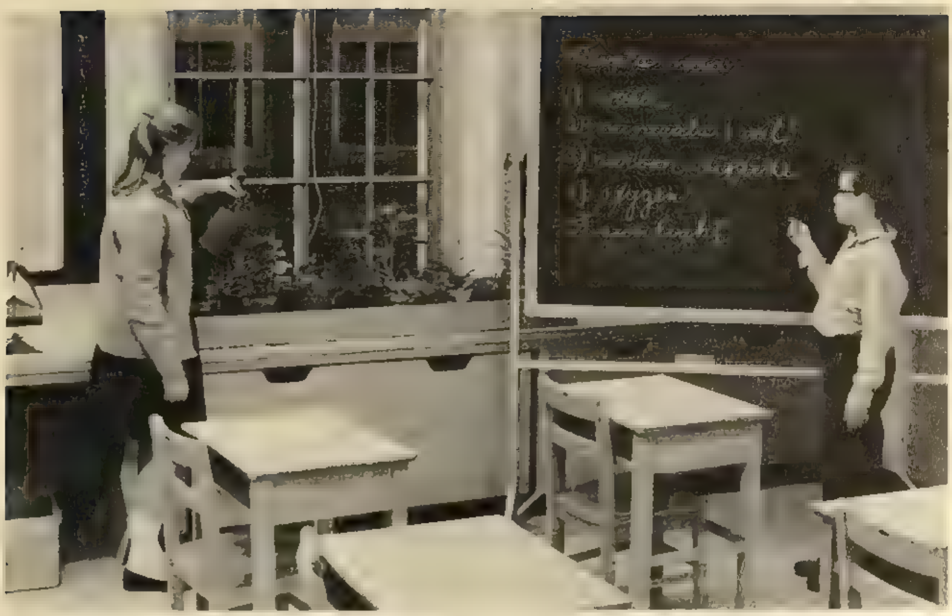
WHAT WOULD the earth be like without any plants? Let us see how important they are to everyday life. Plants are good for the soil because they help prevent erosion. When they die, plants become fertilizer for the soil. Plants purify the air by taking out the carbon dioxide and producing oxygen. They are also important in industry. Perfume is made from the flowers of certain plants; paper is made from trees; and cloth such as cotton and linen also comes from plants. Many homes are built with lumber, and are heated with coal that came from dead plants. People work in their gardens to grow beautiful flowers. But most important, plants are the source of food for all living things. Without plants there would be no life!

In this unit the children will learn the conditions necessary for plant growth, how soil affects their growth, and some of the different ways in which plants are grown. They will also learn that different plants grow in different parts of the country, and that plants grow during certain seasons of the year.

At the completion of this unit, the children should have a greater awareness and interest in plants around them. They should learn how to plan experiments carefully and accurately, and realize the need for a control. They should be able to abstract the main ideas from their reading and report them effectively to the class. They should develop competence in observing accurately and drawing satisfactory conclusions.

BASIC SCIENCE INFORMATION

I. CONDITIONS NECESSARY FOR GROWTH.
   A. All plants need air to grow.
      1. Air is used to make food.
   B. Plants also need water.
      1. Plants need water to make their food.
      2. Plants get the water from the ground.
      3. Some plants need more water than others.



A unit on the care of plants and ways of growing them.

C. Plants cannot grow without light.
   1. Green plants need light to make food.
   2. Usually plants get light from the sun.
   3. Light is needed to keep a plant green.

D. Plants need warmth to grow.
   1. If the temperature becomes too hot or too cold, a plant will stop growing; often it will die.

II. EFFECT OF SOIL.

A. Plants need good earth, or soil, to grow.
   1. Good earth has water and chemicals (called minerals) in it.
   2. Good earth contains sand, clay, and humus—small bits of dead plants and animals.

B. If the soil has too much sand in it, most plants will not grow.
   1. Sandy soil dries out quickly.
   2. Sandy soil does not have enough minerals for most plants.

C. Earth that has too much clay will not have many plants growing in it.
   1. Clay soil holds water, but it gets sticky and gummy and does not let the water get into the plant.
   2. When clay soil becomes dry, it gets as hard as rock.
   3. Dry clay will crush a plant.

D. Good earth, or loam, is the best soil for growing plants.
   1. It holds water well, and also has enough minerals.

III. EFFECT OF CLIMATE, SEASONS, AND WEATHER.

A. Plants grow differently in warm and cold weather.
   1. Some plants grow better where the weather is very hot.

a. They grow better in the South, where it stays warmer longer.
b. They do not grow as well where the summers are short.
c. A palm tree is a plant that needs warm weather.

2. Other plants grow better where the weather is cooler.
   a. In Alaska there is a small red plant that grows in the snow.
3. A maple tree is a plant that grows best where it is neither very hot nor very cold.
4. When the weather gets too cold, some plants will die.

B. Most plants cannot stand the large changes in weather between summer and winter.
1. During the spring, summer, and fall, plants grow beautifully.
2. Many plants live for only one year and then die when the winter cold comes.
3. Most trees lose their leaves when the weather gets cold.
   a. Trees do not die, but they rest during the cold months.
   b. They get new leaves in the spring.
   c. Evergreens have leaves that look like needles, and they stay green all winter.

IV. WAYS OF GROWING PLANTS.

A. Seeds.
1. Most plants grow from seeds.
2. When a seed is planted, roots, stems, and leaves grow.
3. Beans and radishes are seeds that will grow into new plants.

B. Stems.
1. Sometimes a new plant can be grown from a cutting of another plant.
   a. A cutting is usually a piece of the stem with the leaves.
   b. Philodendron and coleus can be grown from cuttings.
2. Many plants grow from bulbs.
   a. A bulb is a stem that grows underground.
   b. Onions, tulips, narcissus, and lilies are all grown from bulbs.
3. A new plant can be grown from a white potato.
   a. A white potato is another kind of underground stem.
   b. The "eye" of a potato is really a small bud.

C. Roots.
1. Some roots will grow into new plants.
2. Carrots, radishes, beets, and sweet potatoes are roots that will grow into new plants.

D. Leaves.
1. Some plants can be grown from leaves.
2. African violets, sedum, and begonias can be grown from leaves.

GENERAL INITIATING ACTIVITY

IF POSSIBLE, this unit should be started during the end of April or the beginning of May, when trees are showing their leaves and flowers are be-

ginning to appear. The teacher will ask the children if they would like to grow some plants for the classroom, and possibly a plant of their own to take home.

With the children's interest and curiosity awakened, the following questions should arise, or be asked by the teacher, during the planning period:

1. What shall we plant?
2. How do we start growing the plants?
3. What must we do when taking care of the plants?

These questions will be put on the chalkboard, and referred to during the unit.

Note: Because a long time is required to test the effect of different conditions on plant growth and to grow new plants, this unit will most likely have to be taught in conjunction with another unit.

NEW SCIENCE VOCABULARY

soil	loam	bulb
minerals	cutting	"eye"
humus		

TEACHER BIBLIOGRAPHY

T–1 Craig, Gerald S., Ruth L. Roche, and John G. Navarra. *Experimenting in Science.* Boston: Ginn, 1958. (Grade 6)

T–2 Hone, Elizabeth B., Alexander Joseph, and Edward Victor. *A Sourcebook for Elementary Science.* New York: Harcourt, 1962.

T–3 Moon, Truman J., Paul B. Mann, and James H. Otto. *Modern Biology.* New York: Holt, Rinehart & Winston, 1956.

T–4 Nelson, Leslie W., and George C. Lorbeer. *Science Activities for Elementary Children.* Dubuque, Iowa: W. C. Brown, 1959.

T–5 Parker, Bertha Morris. *Garden Indoors.* New York: Harper, 1953.

T–6 Thurber, Walter A. *Exploring Science.* Rockleigh, N.J.: Allyn & Bacon, 1960. (Grade 5)

T–7 *UNESCO Source Book for Science Teaching.* New York: UNESCO Publications Center, 1956.

T–8 Craig, Gerald S. *Science for the Elementary-School Teacher.* Boston: Ginn, 1958.

T = Teacher reference.

PUPIL BIBLIOGRAPHY

P–1 BEAUCHAMP, WILBUR L. *Science Is Learning.* Chicago: Scott, 1961. (GRADE 2)

P–2 BLOUGH, GLENN O. *Plants Round the Year.* New York: Harper, 1957.

P–3 JACOBSON, WILLARD J., and CECILIA J. LAUBY. *ABC Science Series.* New York: Am. Bk. Co., 1961. (GRADE 2)

*P–4 NAVARRA, JOHN GABRIEL, and JOSEPH ZAFFORONI. *Today's Basic Science.* New York: Harper, 1963. (GRADE 2)

P–5 SCHNEIDER, HERMAN, and NINA SCHNEIDER. *Science for Here and Now.* Boston: Heath, 1961. (GRADE 2)

†P–6 SCHNEIDER, HERMAN, and NINA SCHNEIDER. *Science for Work and Play.* Boston: Heath, 1961. (GRADE 1)

‡P–7 SILSAM, MILLICENT E. *Play with Plants.* New York: Morrow, 1959.

†P–8 FRASIER, GEORGE WILLARD, HELEN DOLMAN MACCRAHEN, and DONALD GILMORE DECKER. *Science for You.* New York: L. W. Singer, 1959. (GRADE 1)

‡P–9 SCHNEIDER, HERMAN, and NINA SCHNEIDER. *Plants in the City.* New York: Day, 1951.

P = Pupil reference.
* = Basic classroom text.
† = Slow reading level.
‡ = Advanced reading level.

FILMS

F–1 *What Plants Need for Growth.* Wilmette, Ill.: Encyclopaedia Britannica Films. 11 minutes, color.

F = Film.

Initiating Activities and Pupil Objectives	Basic Science Information
Initiating Activity: The children should be shown two plants, one that is healthy and growing, and one that is dead. Thought questions: Why is one plant still growing while the other has died? What do plants need to be healthy and grow?	
	I. Conditions Necessary for Growth.
Do plants need air?	A. All plants need air to grow. 1. Air is used to make food.
Should we water plants?	B. Plants also need water.
	1. Plants need water to make their food. 2. Plants get the water from the ground. 3. Some plants need more water than others.
Why do we plant flowers in the sun?	C. Plants cannot grow without light.
	1. Green plants need light to make food. 2. Usually plants get light from the sun. 3. Light is needed to keep a plant green.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
	Two plants: one growing and one dead.		
Teacher explanation and class discussion.		T–3 p. 170	Do the children contribute to the discussion?
Pupil experiment: A few pupils will water one plant and not water the other for four days. They will report to the class what they did, and will show the rest of the class the results.	Two growing plants.	P–4 p. 52	Do the children have an interest in doing further experimentation?
Teacher explanation followed by class discussion.		T–1 p. 55	Do the children stick closely to the subject under discussion?
------------------------------	------------	------------	------------------
Let a small group experiment by growing one plant in the light and the other in darkness. The group will show the class the results in about five days, and will report what they observed.	Grass seed. Two small flower pots. Soil.	P–4 pp. 50–51	Are the children able to communicate the results (and their interpretations) to the rest of the class?
Teacher explanation and class discussion.		T–1 pp. 127–128	
The class will complete the above experiment (putting the grass back in the sun), and then will proceed to class discussion.	Grass that has been grown in the dark.	P–4 pp. 50–51	Are the children curious?

Initiating Activities and Pupil Objectives	Basic Science Information
Initiating Activity: The children should be shown two plants, one that is healthy and growing, and one that is dead. Thought questions: Why is one plant still growing while the other has died? What do plants need to be healthy and grow?	
	I. Conditions Necessary for Growth.
Do plants need air?	A. All plants need air to grow. 1. Air is used to make food.
Should we water plants?	B. Plants also need water.
	1. Plants need water to make their food. 2. Plants get the water from the ground. 3. Some plants need more water than others.
Why do we plant flowers in the sun?	C. Plants cannot grow without light.
	1. Green plants need light to make food. 2. Usually plants get light from the sun. 3. Light is needed to keep a plant green.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
	Two plants: one growing and one dead.		
Teacher explanation and class discussion.		T–3 p. 170	Do the children contribute to the discussion?
Pupil experiment: A few pupils will water one plant and not water the other for four days. They will report to the class what they did, and will show the rest of the class the results.	Two growing plants.	P–4 p. 52	Do the children have an interest in doing further experimentation?
Teacher explanation followed by class discussion.		T–1 p. 55	Do the children stick closely to the subject under discussion?
- -	- - - - - - - - - - -	- - - - - - - - - - -	- - - - - - - - - - - - - - - - -
Let a small group experiment by growing one plant in the light and the other in darkness. The group will show the class the results in about five days, and will report what they observed.	Grass seed. Two small flower pots. Soil.	P–4 pp. 50–51	Are the children able to communicate the results (and their interpretations) to the rest of the class?
Teacher explanation and class discussion.		T–1 pp. 127–128	
The class will complete the above experiment (putting the grass back in the sun), and then will proceed to class discussion.	Grass that has been grown in the dark.	P–4 pp. 50–51	Are the children curious?

Initiating Activities and Pupil Objectives	Basic Science Information
Do plants have to be warm?	D. Plants need warmth to grow.
	1. If the temperature becomes too hot or too cold, a plant will stop growing; often it will die.
Initiating Activity: Take the children on a walk around the school. Have the children observe the places where they find plants growing; also have them look at the places where they do not find plants growing.	
	II. Effect of Soil.
In what do plants grow, wherever they are found?	A. Plants need good earth, or soil, to grow.
What does good earth, or soil, have in it?	1. Good earth has water and chemicals (called minerals) in it.
	2. Good earth contains sand, clay, and humus—small bits of dead plants and animals.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Teacher explanation followed by class discussion.		T–1 pp. 65–66	
Teacher experiment: Keep one plant hot, one plant cold, and one plant at room temperature (warm). Explain to the class what was done. Follow explanation with class discussion.	Three healthy plants.	T–4 p. 69	Can the children see a cause-and-effect relationship? Do the children recognize the need for a control?
Oral review of the conditions necessary for plants to grow and be healthy.			
------------------------	----------	----------	----------------
			Test: Short objective test on the conditions necessary for plant growth.
------------------------	----------	----------	----------------
Long-range pupil experiment: Have each child plant some seeds in soil, and some in stones. The children will discuss what they observe at the end of the first, second, and third weeks. They will draw their conclusions at the end of the third week.	Jar. Pan. Soil. Stones. Seeds.	P–1 pp. 110–111	Are the children willing to change their opinions in the light of new evidence?
Teacher explanation followed by class discussion.		T–1 p. 56	
Teacher explanation and class discussion.		T–8 p. 503	Are the children able to speak effectively and to the point?
------------------------	----------	----------	----------------

Initiating Activities and Pupil Objectives	Basic Science Information
Initiating Activity: Place three flower pots, containing garden soil, clay, and sand, on the science table. Have the children see and feel the difference. Ask: In which pot will seeds grow the best?	
What happens if there is a lot of sand?	B. If the soil has too much sand in it, most plants will not grow.
	1. Sandy soil dries out quickly.
	2. Sandy soil does not have enough minerals for most plants.
Will plants grow if there is a lot of clay?	C. Earth that has too much clay will not have many plants growing in it.
	1. Clay soil holds water, but it gets sticky and gummy, and does not let the water get into the plant.
	2. When clay soil becomes dry, it gets as hard as rock.
	3. Dry clay will crush a plant.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
	Three flower pots. Garden soil. Clay. Sand.		
Divide the class into three groups. One group will plant five radish seeds in sandy soil, another group will plant five seeds in clay soil, and the third group will plant five seeds in loam. Water each pot with the same amount of water and keep all other conditions the same. Let the class keep a record of results.	Radish seeds. Three flower pots. Sand, clay, and loam.	T–4 p. 72	Are the children keeping a careful and accurate record?
Teacher experiment to show how sand, clay, and loam hold water.	Three small jars. Three juice cans. Masking tape. Clay, sand, and loam.	T–2 p. 79	Are the children able to observe carefully?
Teacher explanation followed by class discussion.		T–8 p. 503	
Observe and discuss the results of the three-group experiment described above.			Can the children interpret the results of an experiment?
Discussion of the experiment showing how soils hold water.			
Teacher experiment to show how hard clay soil becomes when it gets dry. Experiment to be followed by class discussion.	Glass jar or beaker. Clay soil. Water.		Do the children show original thinking?

Initiating Activities and Pupil Objectives	Basic Science Information
What is the best dirt for plants?	D. Good earth, or loam, is the best soil for growing plants. 1. It holds water well, and also has enough minerals.
Initiating Activity: Put up a bulletin-board display. The display should be divided into two parts. One side should have pictures of one area and scene in each of the four seasons. The other half of the bulletin board should have pictures of different kinds of plants growing in different parts of the country.	III. Effect of Climate, Seasons, and the Weather.
Why do not all plants grow where we live?	A. Plants grow differently in warm and cold weather. 1. Some plants grow better where the weather is very hot. a. They grow better in the South where it stays warmer longer. b. They do not grow as well where the summers are short. c. A palm tree is a plant that needs warm weather.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Observe and discuss the results of the three-group experiment described above.			Are the children able to draw conclusions?
Teacher explanation followed by class discussion.		T–8 p. 503	
			Test: "Who am I?" Have each child describe one characteristic of a soil. The child who knows what soil is being described must tell why it is important. The child who has the right answer gets to go next.
	Four pictures of the same area and scene taken in fall, winter, summer, and spring. Pictures of plants growing in different parts of the country.		
Teacher explanation followed by class discussion. Pictures should be used for illustration whenever possible.		T–1 pp. 62–66	Do the children show original thinking?

Initiating Activities and Pupil Objectives	Basic Science Information
Do all plants have to grow where the weather is hot?	2. Other plants grow better where the weather is cooler. a. In Alaska there is a small red plant that grows in the snow. 3. A maple tree is a plant that grows best where it is neither very hot nor very cold. 4. When the weather gets too cold, some plants will die.
Why do some plants die in winter?	B. Most plants cannot stand the large changes in weather between summer and winter. 1. During the spring, summer, and fall, plants grow beautifully. 2. Many plants live for only one year and then die when the winter cold comes.
Why do trees not die?	3. Most trees lose their leaves when the weather gets cold. a. Trees do not die, but they rest during the cold months. b. They get new leaves in the spring. c. Evergreens have leaves that look like needles, and they stay green all winter.
Initiating Activity: Recall experiments where plants were grown from grass and radish seeds. Ask: Is this the only way to grow plants (by seed), or are there other ways of growing plants?	IV. Ways of Growing Plants.
Are many plants grown from seeds?	A. Seeds. 1. Most plants grow from seeds.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Teacher explanation followed by class discussion.		T–1 pp. 62–66	Do the children stay close to the topic under discussion?
Review of experiment of growing plant in refrigerator.			Can the children apply what was learned in a previous experiment to a new situation?
Pupil reading about plants in the different seasons.		P–2 pp. 17–18, 29–30, 4–5	Can the children abstract the main ideas from their readings?
Teacher explanation followed by class discussion.		T–8 p. 607	
Pupil reading followed by teacher explanation, if necessary, and class discussion.		P–2 pp. 15–16	Do the children draw satisfactory conclusions from the reading and discussion?
Teacher explanation and class discussion.		T–8 p. 607	
Teacher explanation, followed by a demonstration of different varieties of seeds. Ask children to suggest other seeds that will produce plants.	Variety of seeds.		Do the children contribute effectively to the discussion?

Initiating Activities and Pupil Objectives	Basic Science Information
	2. When a seed is planted, roots, stems, and leaves grow.
	3. Beans and radishes are seeds that will grow into new plants.
Can plants be grown from stems?	B. Stems.
	1. Sometimes a new plant can be grown from a cutting of another plant.
	a. A cutting is usually a piece of the stem with leaves.
	b. Philodendron and coleus can be grown from cuttings.
Can plants be grown from bulbs?	2. Many plants grow from bulbs.
	a. A bulb is a stem that grows underground.
	b. Onions, tulips, narcissus, and lilies are all grown from bulbs.
Will a plant grow from a white potato?	3. A new plant can be grown from a white potato.
	a. A white potato is another kind of underground stem.
	b. The "eye" of a potato is really a small bud.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Dig up a newly grown plant and observe the parts of the plant.	Radish plant.		
Class experiment growing bean seeds.	Bean seeds. Flower pots or jars.	P–3 p. 89	Are the children planning the experiment carefully?
----------	----------	----------	----------
Pupil reading to be followed by class discussion.		P–3 p. 99	Are the children curious about the meaning of a new and unfamiliar word?
Have two pupils make a cutting from a philodendron plant, and grow roots from the cutting. Follow with a class discussion.	Glass jar. Philodendron cutting.	T–5 pp. 14–15	Are the children able to follow specific directions?
Teacher explanation and class discussion. Bring in bulbs (not growing) for the children to look at and feel.	Bulbs.	T–1 p. 69	
Have some children prepare a suitable container for growing a narcissus bulb, and then have the children plant it.	Narcissus bulbs. Bowl. Pebbles or pearl chips. Small pieces of charcoal.	T–5 pp. 7–10	Are the rest of the children observing the procedure carefully?
Have the class grow a white potato in the classroom.	White potato. Flower pot. Soil.	T–3 pp. 163–164	
Teacher explanation followed by class discussion.		T–3 pp. 163–164	
----------	----------	----------	----------

Initiating Activities and Pupil Objectives	Basic Science Information
Can plants be grown from roots?	C. Roots. 1. Some roots will grow into new plants. 2. Carrots, radishes, beets, and sweet potatoes are roots that will grow into new plants.
Is it possible to grow a new plant from a leaf?	D. Leaves. 1. Some plants can be grown from leaves. 2. African violets, sedum, and begonias can be grown from leaves.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Teacher explanation and class discussion.		T–1 pp. 68–72	Are the children interested in further experimentation?
Have the class grow a root garden. The garden will grow the tops of carrots, beets, and radishes. After two weeks the children will have a discussion on the new plants.	Box. Soil. Tops of beets, radishes, and carrots.	T–7 p. 40	Are the children able to follow specific directions?
Teacher explanation and class discussion.		T–5 pp. 16–17	
Teacher demonstration of a rex begonia leaf that has been started at least two weeks before.	Rex begonia leaves. Shallow box. Sand. Knife. Piece of glass. Four small pieces of wood.	T–5 pp. 16–17	Are the children willing to change their opinions in the light of the evidence?
Culminating Activity: Show film, *What Plants Need for Growth.* Follow with a display of all the plants grown in different ways, with each plant labeled appropriately. Conclude with a question-and-answer period, where all the main concepts in the unit are reviewed.	Projector. Screen.	F–1	

ADDITIONAL LEARNING ACTIVITIES FOR SLOW LEARNERS

Learning Activities	Materials
1. Experiment to show that plants need light.	P–8 pp. 108–109. Seeds. Two cans. Soil.
2. Experiment to show that plants need good soil.	P–8 pp. 100–107. Pan. Jar. Can. Sand. Soil. Seeds.
3. Reading about the effect of the seasons on plants. The children can make a small notebook, drawing the trees in the various seasons.	P–6 pp. 105–109. Colored paper. Crayons.
4. Have the children place a board over a small portion of grass for a week or two to show that plants need sunlight.	T–2 p. 93.
5. Have the children read about where plants grow.	P–5 pp. 72–77.

ADDITIONAL LEARNING ACTIVITIES FOR FAST LEARNERS

Learning Activities	Materials
1. Additional reading on where plants grow. The children can also make a chart of the plants that grow in the area in which they live.	P–3 pp. 72–77.
2. Experiment to show why cactus plants will hold so much water.	P–9 pp. 28–29. Two sheets of paper.
3. Make a water garden.	P–9 pp. 64–66. Aquarium tank or glass bowl. Sand. Water plants. Pebbles or pearl chips.
4. Experiment growing bird seed.	P–9 p. 60. Sponge. Bird seed.
5. Experiment growing an avocado seed.	P–7 p. 28. Avocado pit. Tall jar.
6. Experiment growing pussy willow stems.	P–7 p. 17. Pussy willow stems. Jar or glass.
7. Help slow learners.	
8. Make short oral reports on the effect of the seasons on plants.	

FRICTION

A Unit for Grade 4

SUBMITTED BY: Valerie Kain
Northwestern University

OVERVIEW

FRICTION is a factor constantly present in our daily lives. It influences so much of our environment that it is impossible to overlook the effects it has upon us. There are very few things that we do that are not modified in some way by friction. It is something that the children encounter every day. Sometimes it is a hindrance, and other times it is a help. Children are continually trying to either reduce or increase friction. When the children explore the unit "Machines," which follows immediately, friction will have to be considered throughout the children's observations and experimentations.

This unit attempts to define friction and to determine some of the factors that affect friction. It takes up harmful effects of friction and introduces the children to the different ways and means of reducing friction. Finally, it helps the children realize the many and varied useful effects of friction.

This unit attempts not only to give the children a basic understanding of friction, but also to develop certain values and desirable behaviors. It is hoped that each child will sharpen his curiosity about his environment and be interested in exploring further. He will have an opportunity to make careful observations, think critically, conduct investigations, make judgments, and solve problems. He will read, communicate, and share his thoughts and conclusions with others. And in return, he will keep an open mind when listening to the opinions and findings of his peers.

BASIC SCIENCE INFORMATION

I. WHAT IS FRICTION?

   A. Friction occurs whenever two surfaces rub against each other.

   B. All objects are made up of bumps and hollows.

      1. Some bumps and hollows are large enough to be seen.

      2. Others are much smaller and can only be seen under a magnifying glass.

A unit on friction.

3. Whenever objects rub together, these bumps and hollows catch and stick.
4. Friction is the catching and sticking of the bumps and hollows.

C. There is both rolling and sliding friction.
1. In rolling friction, the object rolls over the bumps and hollows and does not rub so much against the surface.
2. In sliding friction, two objects must rub over each other.

II. FACTORS AFFECTING FRICTION.

A. The surface finish affects friction.
1. There is a small amount of friction when smooth surfaces rub together.
2. The rougher the surface, the greater is the friction.
3. It is impossible to make a perfectly smooth surface.

B. The amount of friction is affected by the pressure of one object on another.
1. The heavier the object, the greater is the pressure and the greater is the friction.

C. The area between objects affects friction.
1. The greater the area, the greater is the friction.

D. Rolling creates less friction than does sliding.

III. HARMFUL EFFECTS OF FRICTION.

A. Friction produces heat that may cause serious damage.
B. Friction makes machines go more slowly.

C. Friction wears out substances.
   1. The rolling parts of machines, if not lubricated properly, will melt or "burn out."
   2. The knees of blue jeans wear out.
   3. The lead in pencils wears down.

IV. Factors That Reduce Friction.
   A. Friction is reduced by making rubbing surfaces as smooth as possible.
   B. Friction is reduced by changing sliding friction to rolling friction.
      1. Wheels reduce friction because they permit the surfaces involved to roll over the bumps and hollows rather than to slide over them.
      2. Ball bearings are steel balls that roll between a wheel and an axle, preventing the wheel from rubbing against the axle so much.
   C. The use of "antifriction" metal, in which certain alloys are formed by combining various metals, has been found to give less friction when used with ordinary metals.
   D. Lubrication reduces friction because it fills in the hollows, covers over the bumps, and prevents catching and sticking.
      1. Solid surfaces actually slide on the lubricant rather than on each other.

V. Useful Effects of Friction.
   A. Friction may be used to slow down moving objects.
      1. Without friction, the brakes in an automobile would be useless.
   B. When anything is moved, some friction results.
      1. We would not be able to walk without friction, because our feet would slip backward.
         a. That is the reason why walking on ice is difficult.
      2. Automobiles and trains would not be able to start without friction between the wheels and the surface beneath.
   C. Everyday activities would be impossible without friction.
      1. Door knobs would slip through our hands without turning.
      2. Chalk would not write on a blackboard.
      3. The violinist's bow would slip silently across the strings.
      4. The force of friction holds nails and screws in walls.
   D. Sometimes we intentionally increase friction for a useful effect.
      1. A baseball pitcher rubs resin on his hands to get a better grip on the ball.
      2. Sand is spread on icy roads.
      3. Chains are put on tires to create more friction in icy weather.
   E. Friction causes heat, which has important uses.
      1. When a match is struck, the heat resulting from friction sets the match on fire.

GENERAL INITIATING ACTIVITY

To arouse interest and raise questions, the teacher will display a poster several days before beginning the unit. It will remain in the classroom throughout the study of the unit. On the poster there will be two rows of six drawings each. In each drawing there will be a boy, smiling if friction is helping him, frowning if friction is hindering him.

Why This?	Why Not This?
1. Picture of a boy in a car with wheels.	1. Picture of the same boy in the same car without wheels.
2. Picture of a gleeful boy sledding in the snow.	2. Picture of a sad boy on a sled on bare ground.
3. Picture of a boy pushing a small stack of books to a friend at the other end of a table.	3. Picture of a boy pushing a large, heavy stack of books to the other end of the table. to the same friend.
4. Picture of a boy playing on his knees with his blue jeans rolled up.	4. Picture of a boy playing on one knee with hole patched up on the visible knee.
5. Picture of a wagon with the word "squeak." The boy watching is sad.	5. Picture of the same wagon, but the boy is smiling as he stands with an oil can in his hand.
6. Picture of a boy walking forward on the sidewalk.	6. Picture of a boy losing balance as he walks on the ice.

In this way the children's attention and curiosity will be focused on at least one key concept that will be learned by exploring each picture farther, as follows: (1) rolling friction is less than sliding friction; (2) the surface affects friction; (3) pressure affects friction; (4) friction can be harmful; (5) lubrication reduces friction; and (6) friction can be useful.

NEW SCIENCE VOCABULARY

friction	sliding friction	wheels	antifriction metal
rolling friction	pressure	ball bearings	lubrication

TEACHER BIBLIOGRAPHY

T–1 Barnard, J. Darrell, *et al. Science: A Search for Evidence.* New York: Macmillan, 1962. (Grade 8)

T–2 Blough, Glenn O., Julius Schwartz, and Albert J. Huggett. *Elementary School Science and How to Teach It.* New York: Holt, Rinehart & Winston, 1958.

T–3 CRAIG, GERALD. *Science for the Elementary School Teacher.* Boston: Ginn, 1958.

T–4 *The General Science Handbook,* Part I. Albany, N.Y.: New York State Education Department, Bureau of Secondary Curriculum, 1951.

T–5 HONE, ELIZABETH B., ALEXANDER JOSEPH, and EDWARD VICTOR. *A Sourcebook for Elementary Science.* New York: Harcourt, 1962.

T–6 VICTOR, EDWARD. *Friction.* Chicago: Follett, 1961.

T = Teacher reference.

PUPIL BIBLIOGRAPHY

‡P–1 BARNARD, J. DARRELL, *et al. The Macmillan Science-Life Series.* New York: Macmillan, 1962. (GRADE 4)

†P–2 BEAUCHAMP, WILBUR L., GLENN O. BLOUGH, and MARY M. WILLIAMS. *Discovering Our World.* Book 2. Chicago: Scott, 1957. (GRADE 5)

*P–3 JACOBSON, WILLARD J., and CECILIA J. LAUBY. *ABC Science Series.* New York: Am. Bk. Co., 1961. (GRADE 2)

*P–4 THURBER, WALTER A. *Exploring Science.* Rockleigh, N.J.: Allyn & Bacon, 1960. (GRADE 2)

*P–5 VICTOR, EDWARD. *Friction.* Chicago: Follett, 1961.

P = Pupil reference.
* = Slow reading level.
† = Advanced reading level.
‡ = Basic text.

FILMS AND FILMSTRIPS

FILMS

F–1 *Friction and its Effects.* Chicago: Coronet, 1960. 11 minutes. (How friction helps or hinders us, effects of friction, uses, disadvantages, and methods of controlling friction are shown in this film.)

FILMSTRIPS

FS–1 *Reducing Friction on Land.* New York: McGraw. 50 frames. (Explains what is meant by friction and describes application of wheels, ball bearings, and lubrication.)

*FS–2 *Friction at Work.* New York: Young America. 46 frames. (Explains how friction can be a help or a hindrance and shows applications of the principles of friction.)

F = Film.
FS = Filmstrip.
* = Filmstrip to help the slow learner.

Initiating Activities and Pupil Objectives	Basic Science Information
Initiating Activity: Have a pupil push a large box across the room. Point out how unevenly the box bumps and catches across the floor.	
	I. What Is Friction?
	A. Friction occurs whenever two surfaces rub against each other.
	B. All objects are made up of bumps and hollows.
	1. Some bumps and hollows are large enough to be seen.
	2. Others are much smaller and can only be seen under a magnifying glass.
Why does the box bump as it does?	3. Whenever objects rub together, these bumps and hollows catch and stick.
	4. Friction is the catching and sticking of the bumps and hollows.
Initiating activity: Have a pupil slide a box across the room and then roll a wagon.	
Why does the wagon roll so much more easily than the sliding box?	C. There is both rolling and sliding friction.
	1. In rolling friction, the object rolls over the bumps and hollows and does not rub so much against the surface.
	2. In sliding friction, two objects must rub over each other.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
	Large box.		
Teacher explanation.			
Demonstration: Teacher shows a model of a microscopic view of bumps and hollows on the surface of two blocks.	Balsa-wood model.		
Experiment: A magnifying glass is passed around the room for the pupils to examine the bumps and hollows on the skin of their hands.	Magnifying glass.	T–3 p. 686	Are the children able to follow specific directions?
Demonstration: Teacher rubs the two blocks of the model together and points out how the bumps and hollows catch and stick.	Balsa-wood model.	T–6 p. 7	Are the children able to observe carefully?
	Large box. Wagon.		
Teacher explanation.		T–1 p. 684	
Roll a toy cart with wheels, then slide a toy cart without wheels, over the balsa-wood model.	Two toy carts. Balsa-wood model.		Can the children apply the abstract explanation to the concrete demonstration?
------------------------	----------	----------	----------------

Initiating Activities and Pupil Objectives	Basic Science Information
Initiating activity: Have a large pupil push a smaller pupil across the floor in a large box. (a) Repeat, pushing box over large sheet of cardboard. (b) Repeat, using two pupils. (c) Repeat, using larger box with one pupil. (d) Repeat, rolling box over broomsticks.	
	II. Factors Affecting Friction.
Why is it easier to push the box over the smoother surface?	A. The surface finish affects friction. 1. There is a small amount of friction when smooth surfaces rub together. 2. The rougher the surface, the greater is the friction. 3. It is impossible to make a perfectly smooth surface.
What happens when more weight is added?	B. The amount of friction is affected by the pressure of one object on the other. 1. The heavier the object, the greater is the pressure and the greater is the friction.
	C. The area between objects affects friction. 1. The greater the area, the greater is the friction.
What happens when the box rolls, rather than slides, across the desk?	D. Rolling creates less friction than does sliding.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
	Two wooden boxes. Large piece of cardboard. Several broomsticks.	T–1 p. 686	
Experiment: Have two pupils rub cotton over various surfaces to show which surfaces have the greater amount of friction.	Fine sandpaper. Rough wood. Smooth wood. Glass pane. Cotton.	P–5 p. 8	Do the children interpret the results of the experiment accurately?
Reading. Discussion of questions at the end of the page.		P–5 p. 35	Can the children abstract the main idea from their reading and apply the ideas?
---	---	---	---
Experiment: Have two pupils show how pressure affects friction by pulling a box without rocks, and then a box with rocks across the teacher's desk by a rubber band, measuring the length of the rubber band each time.	Small box. Rocks. Rubber band. Ruler.	P–1 p. 33	Do the children realize the need for a control?
Experiment: Have two pupils show how area between objects affects friction by pulling a small box, then a larger box, across the desk by a rubber band, measuring the rubber band each time.	Small box. Larger box. Rubber band. Ruler.	P–1 p. 33	Do the children handle equipment effectively?
Experiment: Have two pupils show how rolling affects friction by sliding a box across the desk and then rolling the box over pencils, measuring the length of the rubber band each time.	Small box. Round pencil. Rubber band. Ruler.	P–1 p. 33	
---	---	---	---

Initiating Activities and Pupil Objectives	Basic Science Information
Initiating Activity: How can friction be harmful?	
	III. Harmful Effects of Friction.
How does friction affect an eraser?	A. Friction produces heat that may cause serious damage.
What does friction do to machines?	B. Friction makes machines go more slowly.
How would a child explain scientifically to his mother why he has another hole in his blue jeans?	C. Friction wears out substances. 1. The rolling parts of machines, if not lubricated properly, will melt or "burn out." 2. The knees of blue jeans wear out. 3. The lead in pencils wears down.

Initiating Activities and Pupil Objectives	Basic Science Information
Initiating Activity: Show selected frames from the filmstrip, *Reducing Friction on Land.*	
	IV. Factors That Reduce Friction.
Why was the surface smoothed down?	A. Friction is reduced by making rubbing surfaces as smooth as possible.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Experiment: Have pupils rub their pencil erasers on their desks. After they have rubbed for a while, have each pupil place his eraser immediately against his upper lip to feel the heat.	Pencil eraser.	T–5 p. 422	Are the children able to draw conclusions?
Teacher explanation. Discussion.		T–3 p. 684	Do the children contribute to the discussion?
Teacher explanation.		T–3 p. 684	
Try to have a friendly garage man lend a few worn automobile parts to demonstrate wear. Discussion of other examples of wear.	Worn automobile parts.	T–3 p. 687	Do the children see a cause-and-effect relationship between friction and wear?
----------	----------	----------	----------
	Projector. Filmstrip. Screen.	FS–1	
Reading.		P–1 p. 37	
Group activity: Divide the class into groups. Have each group make up their own experiment to show that smooth objects on smooth surfaces move without much friction, and smooth objects on rough surfaces produce more friction.			Are the children planning the experiment carefully and accurately? Do the children work well together?
Have a member from each group report to the class on their group's idea.			Do the children present the material in a logical sequence?
----------	----------	----------	----------

Initiating Activities and Pupil Objectives	Basic Science Information
How do wheels and ball bearings reduce friction?	B. Friction is reduced by changing sliding friction to rolling friction.
	1. Wheels reduce friction because they permit the surfaces involved to roll over the bumps and hollows rather than to slide over them.
	2. Ball bearings are steel balls that roll between a wheel and an axle, preventing the wheel from rubbing against the axle so much.
	C. The use of "antifriction" metal, in which certain alloys are formed by combining various metals, has been found to give less friction when used with ordinary metals.
How does lubrication reduce friction?	D. Lubrication reduces friction because it fills in the hollows, covers over the bumps, and prevents catching and sticking. 1. Solid surfaces actually slide on the lubricant rather than on each other.
Initiating Activity: How can friction be useful?	
	V. Useful Effects of Friction.
What are some of the useful effects of friction?	A. Friction may be used to slow down moving objects.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Teacher explanation of the wheel and ball bearing.		T–1 p. 184	
Demonstration: Have pupils bring roller skates, both skates with bearings and skates without and note the comparative ease with which the wheels rotate.	Roller skates, with ball bearings and without.	T–2 p. 464	
Demonstration: Teacher shows the principle of the ball bearing by spinning a book on the desk, and then on a lid with marbles placed underneath.	Can lid. Marbles. Book.	T–5 p. 422	Can the children now relate the theory of ball bearings to practical applications?
Teacher explanation.		T–2 p. 84	
Experiment: Teacher rubs two pieces of burnt toast together, then places a layer of jam between the pieces of toast and explains how the jam acts as a lubricant, filling in the bumps and covering over the hollows.	Two pieces of burnt toast. Jam.	T–5 p. 421	
Experiment: Have all pupils dry their hands thoroughly, then rub one finger over a glass. Next pour a little water on the glass, rub one finger over it again. Pupil explanation, written.	Glass. Water.	P–1 p. 36	Can the children apply what is learned from one situation to another?
-----	-----	-----	-----
Reading. Have the pupils suggest other ways to illustrate that friction slows moving things down.		P–1 p. 34	Can the children abstract the main idea from their reading?

Initiating Activities and Pupil Objectives	Basic Science Information
	1. Without friction, the brakes in an automobile would be useless.
	B. When anything is moved, some friction results. 1. We would not be able to walk without friction because our feet would slip backward. a. That is the reason why walking on ice is difficult. 2. Automobiles and trains would not be able to start without friction between the wheels and surface beneath.
Initiating Activity: Ask a pupil to open a jar with cold cream rubbed over the lid.	
How does friction help in everyday life?	C. Everyday activities would be impossible without friction. 1. Door knobs would slip through our hands without turning. 2. Chalk would not write on a blackboard. 3. The violinist's bow would slip silently across the strings. 4. The force of friction holds nails and screws in walls.
When would it be advantageous to have friction?	D. Sometimes we intentionally increase friction for useful effects. 1. A baseball pitcher rubs resin on his hands to get a better grip on the ball. 2. Sand is spread on icy roads. 3. Chains are put on tires to create more friction in icy weather.
	E. Friction causes heat, which has important uses.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Demonstration: Teacher shows how brakes work, using a glass as a brake drum and his hand to represent the brake shoe.	Glass.	T–4 p. 81	
Teacher explanation. Discussion.		T–3 p. 685	Do the children stick closely to the topic under discussion?
----------	----------	----------	----------
	Cold cream. Jar.		
Teacher explanation.			
Demonstration: Teacher shows how difficult it is to open a door when her hands are soapy.	Soap and water.	T–6 p. 31	Can the children now explain why the door was so difficult to open?
Discussion of everyday activities using friction.			
Reading.		P–1 p. 36	
Discussion of other ways we intentionally increase friction.			Can the children apply what they read to explain other phenomena?
Demonstration: Teacher strikes a match against a smooth surface and then against sandpaper.	Match. Glass. Sandpaper.	T–2 p. 686	

Initiating Activities and Pupil Objectives	Basic Science Information
	1. When a match is struck, the heat resulting from friction sets the match on fire.

Learning Activities	Supplies and Equipment	Texts and References	Evaluation
Discussion of why heat is important.			Do the children show critical thinking?
Culminating Activity: Show film, *Friction and Its Effects.*	Projector. Screen.	F–1	
			Overall Evaluation: Written test, objective, together with two or three short-answer questions centered around answering the questions posed in the initiating activity poster.

ADDITIONAL LEARNING ACTIVITIES FOR SLOW LEARNERS

Learning Activities	Materials
1. Read and do activities under "Try It and See." These activities review the basic concepts.	P–3 pp. 18–27.
2. Do these experiments, which review the basic concepts—experimenting with rollers, making a toy wagon, and experimenting with oil. Answer the questions at the end of the section.	P–4 pp. 130–144.
3. View filmstrip, *Friction at Work*.	FS–2. Projector, screen.
4. Make a list of some things it would be impossible to do if we did not have friction.	
5. Read basic concepts, perform experiments, and pay special attention to "What Have We Learned About Friction."	P–5 pp. 1–29.

ADDITIONAL LEARNING ACTIVITIES FOR FAST LEARNERS

Learning Activities	Materials
1. Help the slow learners.	
2. Read and report on how we can make machines work better.	P–2 pp. 93–97.
3. Make a collection of some different kinds of lubricants.	
4. Show how Indians made fire by rubbing two sticks together.	*Boy Scout Handbook.*
5. For centuries men have, from time to time, claimed to have made perpetual motion machines. Such machines are supposed to run forever after being started. Do you think this is possible? Why or why not?	
6. Find out why a sled will slide on ice, but not on glass, since glass is probably as smooth as ice (lubrication principle).	
7. Find out how we can tell when something needs oil and bring some examples to class.	P–5 p. 31.

ELECTROMAGNETS

A Unit for Grade 6

SUBMITTED BY: Barbara Hostetler
Northwestern University

OVERVIEW

I. What an Electromagnet Is and What It Does

II. How Electromagnets Are Made

III. How an Electromagnet Is Like a Permanent Magnet

IV. How an Electromagnet Differs from a Permanent Magnet

V. How an Electromagnet Can Be Strengthened

VI. Uses of Electromagnets

GENERAL INITIATING ACTIVITY

To stimulate curiosity and raise questions that will lead into the study of this unit, the teacher will demonstrate some electromagnetic magic (described in Teacher Reference T–1, pages 184–186). In the demonstration there is a large piece of cardboard with an insulated copper wire placed beneath the cardboard in the shape of a question mark. The wire is connected to a dry cell and a switch. Iron filings are scattered on the top of the cardboard. When the switch is pushed, electricity flows through the wire. This produces magnetic effects that pull the iron filings toward the wire, and forms a question mark.

The children will probably be very surprised and rather mystified to see this question mark form. They will probably ask such questions as these:

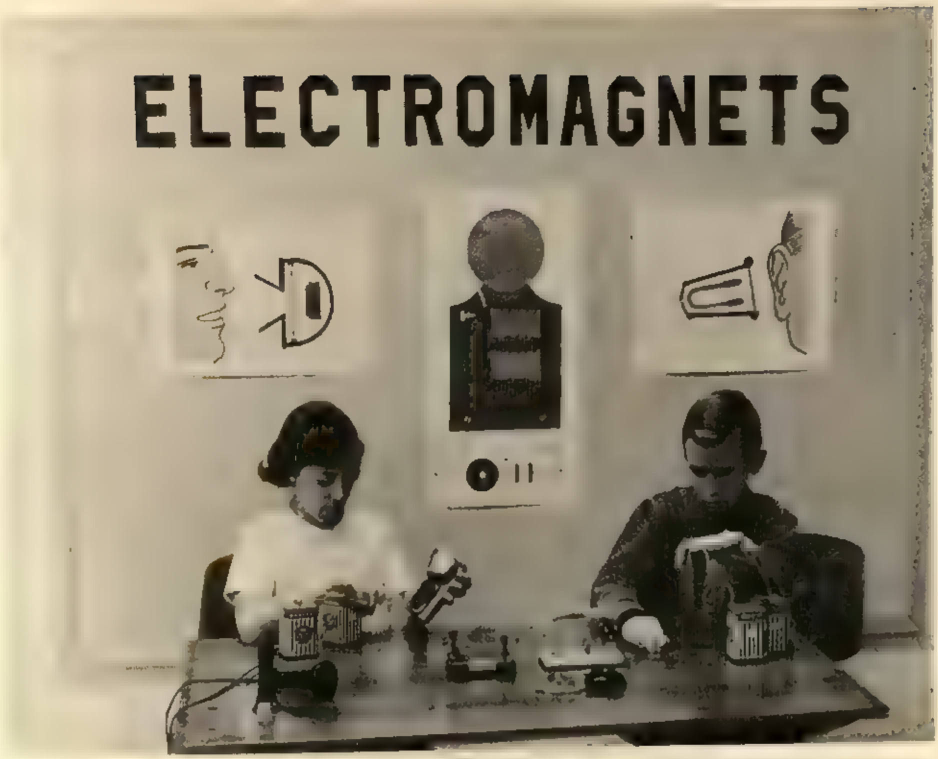
How does it work?

Why do those pieces of metal form a question mark?

What are those pieces of metal made from?

What moves the pieces of metal?

These questions and others that might be asked will be written on a large poster board at the front of the room. As the children learn the answers to all of these questions during the unit, these answers will be written on the poster board.



A unit on electromagnets.

NEW SCIENCE VOCABULARY

attract	electromagnet	magnetic field	repel
cobalt	insulated wire	nickel	temporary magnet
coil	law of magnetic attraction	permanent magnet	terminals
core	lines of force	relay	transformer
electric current			

TEACHER BIBLIOGRAPHY

T–1 Herbert, Don. *Mr. Wizard's Science Secrets.* New York: Hawthorn, 1952.

T–2 Hone, Elizabeth, Alexander Joseph, and Edward Victor. *A Sourcebook for Elementary Science.* New York: Harcourt, 1962.

T–3 Ruchlis, Hyman, and Harvey B. Lemon. *Exploring Physics.* New York: Harcourt, 1952.

T–4 *UNESCO Source Book for Science Teaching,* New York: UNESCO Publications Center, 1962.

T = Teacher reference.

PUPIL BIBLIOGRAPHY

*P–1 BARNARD, J. DARRELL, CECILIA STENDLER, and J. MYRON ATKIN. *The Macmillan Science-Life Series.* New York: Macmillan, 1962. (GRADE 5)

P–2 BEAUCHAMP, WILBUR L., MARY M. WILLIAMS, and GLENN O. BLOUGH. *Discovering Our World.* Book 3. Chicago: Scott, 1957. (GRADE 6)

*P–3 BEAUCHAMP, WILBUR L., MARY M. WILLIAMS, and GLENN O. BLOUGH. *Discovering Our World.* Book 1. Chicago: Scott, 1957. (GRADE 4)

*P–4 CRAIG, GERALD S., and BEATRICE D. HURLEY. *Discovering with Science.* Boston: Ginn, 1958. (GRADE 4)

†P–5 DAVIS, IRA C., JOHN BURNETT, and E. WAYNE GROSS. *Science: Observation and Experiment.* New York: Holt, Rinehart & Winston, 1958. (GRADE 7)

*P–6 PARKER, BERTHA MORRIS. *Magnets.* New York: Harper, 1956.

‡P–7 THURBER, WALTER A. *Exploring Science Six.* Rockleigh, N.J.: Allyn & Bacon, 1960. (GRADE 6)

*P–8 YATES, RAYMOND F. *Boy's Book of Magnetism.* New York: Harper, 1950.

P = Pupil reference.
* = Slow reading level.
† = Advanced reading level.
‡ = Basic classroom text.

FILMSTRIPS

FS–1 *Electromagnets at Work.* New York: Scribner. 30 frames.

FS = Filmstrip.

WORK

INITIATING ACTIVITIES AND PUPIL OBJECTIVES	BASIC SCIENCE INFORMATION
Initiating Activity: Demonstrate a simple electromagnet, picking up iron tacks, steel paper clips, and iron filings.	

SHEETS

Learning Activities	Supplies and Equipment	Texts and References
	Dry cell. Insulated wire. Large iron nail. Iron filings. Iron tacks. Paper clips.	T–2 pp. 352–353

Initiating Activities and Pupil Objectives	Basic Science Information
	I. What an Electromagnet Is and What It Does.
What kind of magnet is this?	A. An electromagnet is a magnet made by passing electricity through a coil of wire wrapped around a soft iron core.
What is the wire for? What is the dry cell for?	B. The current of electricity flowing through the wire causes the magnetism.
Where does the magnetism come from?	1. As the electricity flows through the wire it causes a magnetic field around the wire. 2. In the magnetic field are lines of force and they show where the magnetic field is located and how it is arranged.
Why did the tacks fall off the nail when the wire was disconnected?	C. An electromagnet is a temporary magnet which means that it is magnetic at some times and not magnetic at other times. 1. An electromagnet is a magnet only when electricity is flowing through the coil of wire. 2. When electricity stops flowing through the coil, the electromagnet loses its magnetic power and is no longer a magnet.
Initiating Activity: Demonstrate that a coil of wire carrying electricity will pick up steel wool cuttings.	
Is the coil of wire an electromagnet?	D. Scientists have found that a coil of wire carrying electricity will behave like an electromagnet even without the iron core. 1. This electromagnet is very weak. 2. The addition of the soft iron core greatly strengthens the electromagnet.

Learning Activities	Supplies and Equipment	Texts and References
Reading, followed by teacher explanation and class discussion.		P–6 pp. 208–209 T–3 pp. 385–386
(Have two pupils begin the construction of a crane.)		P–7 pp. 214–217
Teacher demonstration showing the magnetic field of an electromagnet, followed by teacher explanation and class discussion.	Sheet of cardboard. Dry cell. Bell wire. Switch. Iron filings.	T–3 pp. 385–386 T–1 p. 186
------------------------------	------------------	------------
Pupil demonstration of a homemade crane that collects and lifts tacks, then deposits them in another place.	Homemade crane setup.	P–7 pp. 214–217
------------------------------	------------------	------------
	Dry cell. Insulated wire. Steel wool cuttings.	T–2 p. 351
Teacher explanation, followed by class discussion.		T–2 p. 351 T–3 p. 386
Teacher experiment: Show how a coil picks up only some steel wool cuttings; however, when the iron nail is inserted, the coil picks up many more cuttings.	Dry cell. Insulated wire. Iron nail. Steel wool cuttings.	T–2 p. 351

Initiating Activities and Pupil Objectives	Basic Science Information
What materials will an electromagnet attract?	E. An electromagnet will attract only materials made of iron, steel, cobalt, and nickel. 1. They are called *magnetic materials.* 2. An electromagnet will not attract non-magnetic materials such as glass, cloth, rubber, wood, tin, or lead.
Initiating Activity: Ask the pupils if they would like to make an electromagnet.	
	II. How Electromagnets Are Made.
What materials will be needed? How should they be put together?	A. An electromagnet is made by wrapping insulated copper wire around a soft iron core, such as an iron nail, and connecting the bare ends of the wire to the terminals (posts) of a dry cell.
What happens when they are all connected?	1. The iron nail and coil become a magnet, which attracts magnetic materials.
What happens when the electric current is turned off?	2. When the current in the wire coil is turned off, either by a switch or by disconnecting the wire from the dry cell, the magnetism disappears, and the nail and coil no longer act like a magnet.
Does the electromagnet have poles, as does a magnet?	B. The electromagnet has two poles: a north-seeking and a south-seeking pole.
How can we tell which end of an electromagnet is the north-seeking pole and which end is the south-seeking pole?	C. The poles of the electromagnet can be identified by bringing the electromagnet near a compass. 1. The compass needle is a permanent magnet, with a north-seeking and a south-seeking pole. 2. Usually the north-seeking pole of a compass needle is painted blue or black. 3. If the north-seeking pole of the compass needle is attracted to the head of the nail, the head is the south-seeking pole of the electromagnet.

Learning Activities	Supplies and Equipment	Texts and References
Pupil experiment: See which materials an electromagnet will and will not attract.	Electromagnet. Copper tacks. Iron tacks. Brass paper clips. Steel paper clips. Wood. Glass. Tin can (top). Rubber eraser.	P–2 p. 144 P–7 p. 209
Pupils make a simple electromagnet under teacher supervision.	Electromagnets. Tacks.	P–7 pp. 208–209
Pupil experiment: Bring one end of an electromagnet near the north- and south-seeking poles of a suspended bar magnet.	Electromagnet. Bar magnet.	P–2 p. 152
Pupil experiment: Identify the poles of an electromagnet.	Electromagnet. Compass.	P–7 pp. 212–213

Initiating Activities and Pupil Objectives	Basic Science Information
	4. If the north-seeking pole of the compass needle is repelled by the head of the nail, the head is the north-seeking pole of the electromagnet.
What law explains the behavior of the compass needle?	D. The electromagnet follows the law of magnetic attraction. 1. Like poles repel each other. 2. Unlike poles attract each other.
Do the poles of an electromagnet always stay the same?	E. The poles of an electromagnet can be changed by making the electricity flow in the opposite direction from which it flowed originally. 1. This change can be made by changing the connections to the terminals of the dry cell.
Initiating Activity: Show the class an electromagnet and a permanent bar magnet.	
	III. How an Electromagnet Is Like a Permanent Magnet.
How are electromagnets like permanent magnets?	A. They both have north-seeking and south-seeking poles.
	B. They both attract or repel other magnetic poles.
	C. They both attract magnetic materials.
	D. They are both made of magnetic materials.
	E. They both have the same magnetic pattern when iron filings are sprinkled around them.

Learning Activities	Supplies and Equipment	Texts and References
Teacher and pupil discussion.		P–3 pp. 147–148 P–2 p. 152
Teacher experiment: Change the flow of electricity. Check the poles with a compass.	Electromagnet. Compass.	T–2 pp. 352–353
	Electromagnet. Bar magnet.	
Pupil experiment: Check the poles of an electromagnet and a permanent bar magnet.	Electromagnet. Bar magnet. Compass.	P–7 pp. 212–213
Pupil experiment: Bring together the ends of two electromagnets. Then bring together the ends of two permanent bar magnets.	Two electromagnets. Two bar magnets.	P–3 pp. 147–148
Pupil experiment: Show that both electromagnets and permanent magnets attract the same materials.	Electromagnet. Bar magnet. Tacks, paper clips. Wood, glass.	P–7 pp. 208–209
Teacher explanation, followed by class discussion.		T–3 pp. 370–371, p. 385
Teacher experiment: Show the magnetic field of the permanent magnet and electromagnet.	Bar magnet. Electromagnet. Iron filings. Cardboard.	

Initiating Activities and Pupil Objectives	Basic Science Information
	F. They both have magnetic force that can pass through nonmagnetic materials like paper, glass, wood, air, copper, or brass.
Initiating Activity: Show the electromagnet and permanent bar magnet again.	
	IV. How an Electromagnet Differs from a Permanent Magnet.
How is an electromagnet different from a permanent bar magnet?	A. An electromagnet is temporary and can be controlled so that its magnetic power can be turned on and off; a permanent magnet cannot be controlled and is always magnetic.
	B. An electromagnet is made with a soft iron core; a permanent magnet is made of steel.
	C. The poles of an electromagnet can be changed by reversing the flow of electricity; the poles of a permanent magnet cannot be changed.
Initiating Activity: Ask the pupils for suggestions on how to make electromagnets stronger.	
	V. How an Electromagnet Can Be Made Stronger.
What does the piece of iron in a coil of wire do to the electromagnet?	A. An electromagnet can be strengthened by placing a piece of soft iron in the center of a coil of wire.
What would happen if we used more turns of wire?	B. An electromagnet can be strengthened by adding more turns of wire.
What would happen if we used more dry cells?	C. An electromagnet can be strengthened by increasing the electric current flowing through the wire.

Learning Activities	Supplies and Equipment	Texts and References
Pupil experiment: Show that the magnetic force of both electromagnets and permanent bar magnets can pass through paper, glass, wood, and air.	Bar magnet. Electromagnet. Thin sheet of glass. Wood, paper. Iron filings.	T–4 p. 160 T–1 p. 185
	Bar magnet. Electromagnet.	
Pupil experiment: Show that tacks fall off the electromagnet when the electricity is turned off, but remain on the permanent magnet.	Bar magnet. Electromagnet. Tacks.	P–7 pp. 208–209 P–2 p. 144
Teacher explanation.		T–2 pp. 352–353
Recall experiment showing how the poles of an electromagnet can be changed.		T–2 pp. 352–353
Recall experiment showing how a coil carrying electricity is strengthened by inserting a large iron nail.		T–2 pp. 352–353
Pupil experiment: Strengthen electromagnet by adding more turns of wire. (Note: Do the experiment three times and take an average.)	Electromagnet. Tacks.	P–7 pp. 210–211
Pupil experiment: Strengthen an electromagnet by increasing the electric current flowing in the coil. (Note: Do the experiment three times and take an average.)	Electromagnet. Two dry cells. Tacks.	P–7 p. 211

Initiating Activities and Pupil Objectives	Basic Science Information
Can an electromagnet be strengthened in any other way?	D. An electromagnet can be strengthened by bending the soft iron rod into a U-shape or horseshoe, and then winding the wire around it. 1. This method brings the lines of force closer together and concentrates them, making the magnetic force greater.
Initiating Activity: Demonstrate a paper-clip motor. Call attention to electromagnet in it.	
	VI. Uses of Electromagnets.
For what purpose is the electromagnet in the motor?	A. Electromagnets are used in motors to convert electrical energy into mechanical energy.
How are electromagnets used in our transportation systems?	B. Electromagnets are used in our transportation systems for making the following items: 1. Switches. 2. Relays. 3. Trains. 4. Elevators. 5. Cranes.
How are electromagnets used in our communication systems?	C. Electromagnets are used in our communication systems for making the following items: 1. Telegraph equipment. 2. Electric buzzers. 3. Electric bells and chimes. 4. Telephone equipment. 5. Teletype equipment. 6. Tape recorders. 7. Loudspeakers.

Learning Activities	Supplies and Equipment	Texts and References
Teacher experiment: Show how to strengthen an electromagnet with a U-shaped bar. Do control experiment first. (Note: Do the experiment three times and take an average.) (Have some pupils start on the construction of a telegraph, buzzer and bell setups.)	U-shaped iron bar. Copper wire. Tape. Two dry cells. Tacks. Sheet of wood.	T–4 p. 176
	Paper-clip motor.	T–2 p. 377
Pupil demonstration of a motor run by electromagnets.	Toy motor. Dry cells.	P–5 pp. 237–238 P–2 pp. 151–154
Oral reports on the uses of electromagnets in our transportation systems.		P–8 pp. 235–240
Pupil demonstration showing how a telegraph works.	Telegraph setup.	P–7 pp. 220–221 P–2 pp. 146–148
Pupil demonstration showing how an electric buzzer works.	Electric buzzer. Dry cells.	P–7 p. 222
Pupil demonstration of how an electric bell works.	Electric bell. Dry cells.	P–7 p. 223
Oral report on the other uses of electromagnets in our communications systems.		P–2 pp. 146–150 P–7 pp. 220–226

Initiating Activities and Pupil Objectives	Basic Science Information
What are some of the uses of electromagnets in our homes?	D. Electromagnets are used at home in the following appliances: 1. Refrigerators. 2. Electric sewing machines. 3. Motor appliances.

Learning Activities	Supplies and Equipment	Texts and References
Oral report on the uses of electromagnets in the home.		P–2 pp. 152–155 P–4 pp. 178–181 P–5 pp. 236–237
Culminating Activity: Filmstrip, *Electromagnets at Work.*	Projector. Screen.	FS–1
Test: Written objective test covering the entire unit.		

ADDITIONAL LEARNING ACTIVITIES FOR SLOW LEARNERS

Learning Activities	Materials
1. Oral and written reports to explain the law of magnetic attraction as a review of magnets in grade 4. Follow-up with a demonstration in class.	P–3 pp. 147–148. P–7 pp. 3–36. Two permanent magnets.
2. Oral and written reports on the uses of electromagnets in our daily lives. Follow-up: Collect pictures of electromagnets at work for a bulletin-board display.	P–4 pp. 178–181. P–8. Colored pictures. Construction paper and crayons.
3. Allow the children to make their own simple electromagnet.	P–2 p. 142. Insulated copper wire, dry cell, large iron nail.
4. Have the children compile a list of the safety rules that should be followed when using electric current. Follow-up: Put these rules on a large piece of poster board and place in the classroom.	P–2 pp. 143–154. Poster board, crayons.
5. Have the children write a report on this problem: "Suppose that you connected a toy motor and a switch to a dry cell, but the motor would not run. What things would you check to find out why the motor did not go?"	P–7 pp. 208–209.
6. Encourage the children to visit a telegraph office and see how messages are sent. Follow-up: Report in class.	

ADDITIONAL LEARNING ACTIVITIES FOR FAST LEARNERS

Learning Activities	Materials
1. Experiment to show the magnetic effects in a crane. Construct a homemade crane and bring to class for demonstration.	P–7 pp. 214–220. P–2 pp. 143–145. Board, block of wood, long thin pieces of wood, tin can, screws and screw eyes, string, dry cell, insulated copper wire, stove bolt, washers.
2. Oral reports on the poles of a magnet, electromagnet, and the earth. Follow-up by drawing a globe on its axis and explaining the magnetism of the poles to the class.	P–7 pp. 208–209. Construction paper, crayons.
3. Experiment to show a motor run only by electromagnets. Construct the motor and bring to class for demonstration.	P–5 pp. 237–238. P–2 pp. 151–154. Four large iron nails, one piece of wood, one cork, insulated copper wire, one piece glass tubing, two dry cells.
4. Experiment to show how an electric buzzer works. Construct an electromagnet buzzer and bring to class for demonstration.	P–7 pp. 222–223. Two blocks of wood, two nails, insulated copper wire, dry cell, two levers.
5. Oral and written reports on the uses of electromagnets around the house. Follow-up: Report in class.	P–5 pp. 236–237.
6. Read about laying the first telegraph cable across the Atlantic Ocean.	Library resources.
7. Read about Alexander Graham Bell and the invention of the telephone.	Library resources.
8. Look for stories in the newspaper about accidents with electric current. Cut out the stories and make a safety scrapbook of these stories to show in class.	Newspapers, construction paper, crayons.

Learning Activities	Materials
9. Experiment to show how a telegraph works. Construct a simple telegraph to bring to class for demonstration.	P–7 pp. 220–221. P–2 pp. 146–148. Two blocks of wood, tin can, three iron nails, insulated copper wire, dry cell, three screws, two levers.
10. Experiment to show the magnetic effects of electromagnets by the "floating tennis ball" experiment.	Teacher explanation and T–1 p. 200. Dry cell, insulated copper wire, large iron nail, cardboard box, table tennis ball, paper clip, thread, switch.
11. Experiment to show the magnetic effects of an electromagnet by the "jumping jack electromagnet" experiment.	Teacher explanation and T–1 p. 189. Wood, insulated copper wire, nails, switch, dry cell, mercury, bolt.
12. Experiment to show how an electromagnet is used to make an electric door bell. Follow-up: Bring to class for demonstration.	Teacher explanation and T–1 p. 199, P–7 p. 222. Piece of wood, bolt, insulated copper wire, dry cell, tin can, nails, screw, tacks, rubber band, switch.
13. Help the teacher explain experiments and concepts to the class and to the slow learners.	

CHAPTER

7

Materials *for* Teaching Science

All planned elementary science programs, whether newly organized or well established, must have an adequate supply of materials available. Quantity alone is not enough. The success of any science program largely depends upon both the quantity and quality of the materials that can be utilized when needed. The need for all kinds of materials is obvious. When developing or evaluating the science program, the teachers should have ample opportunity to consult professional and scientific literature, and to examine existing courses of study. In the classroom the children must have easy access to supplies and equipment, textbooks and other printed materials, films, filmstrips, models, specimens, and charts. Teachers and children both need adequate facilities so that they can work and explore effectively in science.

Even today, many school systems have made little, if any, provision for supplying their schools with science materials. There are several reasons that may be offered to account for this condition. First, when science

programs in the elementary school are fragmentary or nonexistent, there is little need for science materials. Second, many teachers with an inadequate science background are reluctant to teach science because they are unfamiliar with the science content and equipment. These teachers, therefore, rarely request that the schools furnish them with science materials. Third, to encourage the teaching of elementary science, both teachers and administrators have been told repeatedly that science in the elementary school should be kept simple, and that, when possible, the materials used should be equally simple. This recommendation is sound. To many teachers, however, it has been transformed into a fixed impression that all science materials should be homemade or improvised and that consequently there is no need to allocate or furnish funds for science materials. Fourth, it is assumed that, if there should be an occasional unprecedented need for specific equipment, the equipment can be borrowed without trouble from the junior or senior high school.

These attitudes have created a hardship on many science-minded teachers who are interested in and anxious to teach science to the children. It is often very time-consuming to construct or look for needed equipment. Many worthwhile learning activities call for materials that cannot be found at hand or be homemade. Often teachers have had to wheedle money from the school petty cash fund, or else pay for the needed equipment themselves. It can often be dissatisfying or fruitless to try to borrow equipment from the junior or senior high school. These schools usually operate on a tight budget, and are sometimes pressed to meet their own needs, let alone the needs of others. Even when they do have equipment that can be loaned, the request from the elementary teacher may be made while the equipment is being used or is reserved for use in the near future, and is therefore unavailable. When equipment is loaned to the elementary teacher, such a short time may be imposed upon the loan that the teacher is pressed to make full and satisfactory use of the equipment in the time allotted. There is also the problem of contacting the secondary school teacher to make suitable arrangements for getting together. Both elementary and secondary school teachers are confined to their schools during the day, and the equipment must be picked up and returned after school hours. Finally, if the equipment should be returned damaged or broken, the possibility of further borrowing becomes quite remote. For all of these reasons science learning in the elementary school has been consistently hampered.

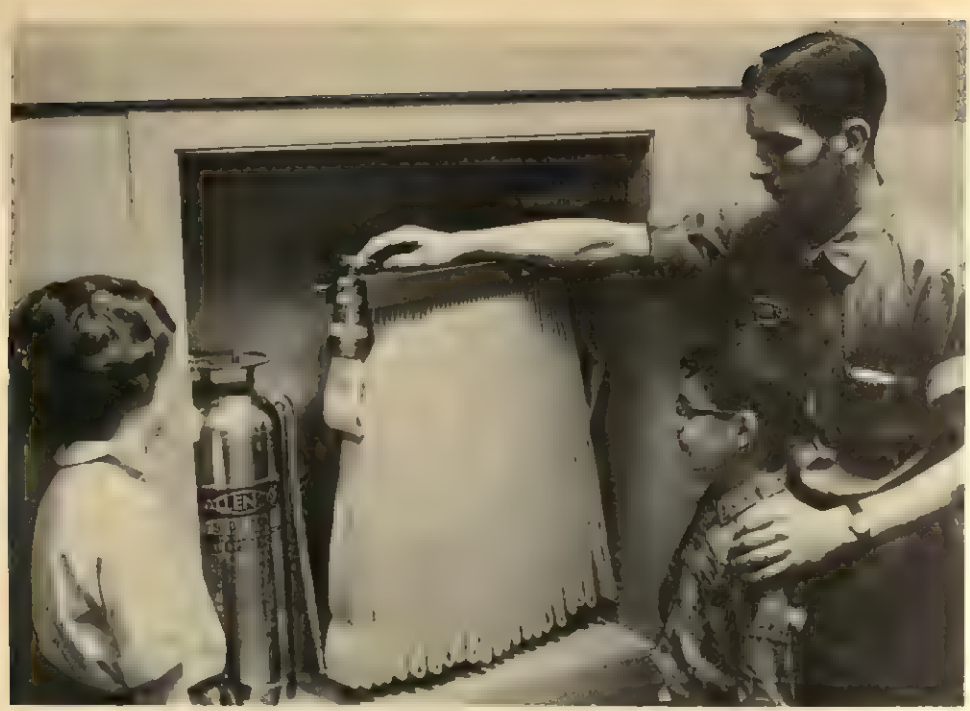
The strong emphasis upon science during the past few years has resulted in a trend toward the growth of highly active and effective elementary science programs. Both the public and the government consider such programs advisable, and have expressed their willingness to support them. All of these newly developed programs call for a wide variety of materials, without which the programs will be ineffective. Consequently, it has become quite evident that the schools must now establish a definite policy about furnishing funds for science materials. Annual budgets should be created, providing for both the purchase of new equipment and the re-

Science programs call for a wide variety of materials.

placement of worn-out or used-up equipment. The National Defense Education Act of 1958, Title III, can and does help the schools immeasurably to meet the large cost of initial outlay for materials, thus enabling the schools to continue to purchase needed materials each year.

The schools should also make a small petty cash fund available throughout the year so that incidental needs and emergency replacements can be met without having to wait for the annual order. Furthermore, administrative procedures should be created to help in the ordering of supplies and equipment. These procedures involve helping the teachers make their orders correctly, collecting and pooling the orders from each school, sending the orders to the various supply houses, and distributing the materials when they arrive.

It should be stressed that the materials should be built around the program, rather than the program around the materials. The decision about what should be taught in the program, and the kinds of learning activities that will be used, should determine what science materials will be needed. If the program is based upon a developed course of study, it would seem logical to list the materials necessary to carry out the suggested learning activities described in the course of study. This list would contain the needed materials for the science program. If the learning activities vary from school to school, the lists should also vary slightly to allow for individual differences. The same procedure would apply if the course of study were based upon a single, or multiple, elementary science textbook



Many materials that are useful for teaching and learning science may be found in the school.

series. In all cases, however, the needed materials would be selected after the course of study had been developed.

Obtaining Supplies and Equipment

OF ALL the areas in the elementary school curriculum, science holds a unique position. Science alone offers the children a multitude of opportunities to do experiments and demonstrations. When the children work with a wide variety of materials learning experiences become real and not vicarious. Manipulative skills are developed in the process. By handling and operating some of the same kinds of materials that scientists use, the children can acquire a little of the flavor of science and at the same time gain greater insight into the different ways that scientists work.

USING SIMPLE MATERIALS WHEN POSSIBLE

In general it is best to use simple supplies and equipment in the elementary school. When simple materials can be as effective as the more complicated materials in evolving or illustrating a science concept, it is preferable to use the simple materials. Complex equipment often tends to confuse the children and distract their attention from the experiment itself, thus interfering with the process of learning. Also, principles learned by using complex equipment may often become isolated in the children's minds

so that the children do not see the connection between the principles and the phenomena in their daily environment. Simple materials are inexpensive and, when damaged or broken, can be replaced much more easily than complicated, more expensive materials.

Many materials that are extremely useful in teaching and learning science may be found in the school itself. The pencil sharpener, door knob, door latch, and curtain or window pulley are excellent examples of machines. Some of the newer schools have ramps instead of stairways, and they can be used to teach the principles of the inclined plane. The school's piano, other musical instruments, bells, and the public address system are available for studying sound, music, and communications. The thermometer and thermostat can introduce learning about heat, temperature, and expansion and contraction of materials. The school's heating, lighting, and electrical systems are conveniently near for observation and study. When its front lens is removed, the filmstrip or slide projector becomes an excellent source for a beam of light. A globe of the earth enables the children to learn the reason for day and night, the seasons, solar and lunar eclipses, and air masses. A gooseneck lamp, with the shade removed, serves as the sun. Maps help in the study of climate, kinds of terrain, and location of natural resources.

On the school grounds, there are many evidences of erosion, although on a smaller scale. The children can observe small gullies formed by rain water, roots of trees that are exposed, dust spatters on basement windows, and rock that has been weathered. There are trees, plants, flowers, seeds,

Some equipment can be homemade.

and all kinds of insects to be studied. Weather phenomena can be observed throughout the year. Teeter-totters, slides, and swings are present for experiments. Several specimens of rock can be collected and examined.

At home there are a wide variety of tools that can be used in the study of machines. In the workshop there are hammers, pliers, wire cutters, screw drivers, chisels, saws, and drills. In the kitchen there are knives, scissors, egg beaters, can openers, corkscrews, mops, and brooms. In the garden there are garden shears, wheel barrows, axes, shovels, hoes, and rakes. Toys are wonderful materials for teaching science. There are carts, wagons, bicycles, balls, bats, fishing poles, roller skates, electric trains, Tinker Toys, Erector sets, and chemical sets.

HOMEMADE OR IMPROVISED EQUIPMENT

In the past, when little or no funds were available for commerical supplies and equipment, many of the learning materials were homemade or improvised. Many of these materials proved to be valuable teaching devices and are still extremely popular today. There will always be a place for this kind of equipment, provided that the learnings that result are worthwhile and the teachers or pupils do not have to spend undue time and effort in either finding the materials or making the equipment.

All kinds of useful homemade equipment are used constantly in science programs throughout the country. Several examples of these kinds of equipment and how they may be constructed are described in detail later in this textbook. They include such equipment as an electric switch, telegraph set, simple electric motor, galvanometer, convection box, ball-and-ring expansion apparatus, unequal expansion bar, smoke box, sonometer, constellation box, wooden stands and supports, balance, animal cage, insect cage, bird feeder, aquarium, and terrarium.

Improvised materials are found in every elementary school classroom where science is taught. Tin cans, glass jars, bottles, pots and pans, cookie and pie tins—of all sizes and shapes—are common. Plastic straws are used instead of glass tubing. Pyrex pots and pans are substitutes for beakers. Pyrex baby bottles have served as test tubes on occasion. Often, when litmus paper is unavailable for detecting if solutions are acid or alkaline, the juice from boiled red cabbage has been used.

A constant difficulty for most elementary school teachers is the problem of obtaining a source of heat because heating is required in many experiments. There are various ways of overcoming this problem. The simplest source of heat, naturally, is a candle. A candle is not very good, however, where steady or much heat is required. Also, the flame tends to deposit soot. Canned heat is much better. It gives a colorless flame that is quite hot. There are small stoves available for use with canned heat, upon which metal and Pyrex vessels can be rested.

An alcohol burner is a good source of heat. It can be purchased commercially or, if the teacher wishes, can be homemade. A homemade alcohol burner uses a small glass jar with a metal screw-on cap as the container. A kerosene lamp wick can be obtained from the hardware store. To provide

Commercial supplies and equipment are also necessary.

an opening for the wick, the metal cap should be unscrewed and placed upon a piece of scrap wood, with the top of the cap resting on the wood. A screw driver, or a chisel, and a hammer should be used to punch a rectangular slit outward in the metal cap. The slit should be long enough and wide enough so that the kerosene wick can be pulled through the slit easily. Now one end of the wick should be slid through the slit, the jar filled with alcohol, the cap pulled onto the jar, and the homemade burner will be ready for use. Wood or grain alcohol can be used as the fuel. When the burner is not being used, the alcohol will continue to rise up the wick and evaporate unless steps are taken to prevent this evaporation. There are several ways of doing this. One way is to pour the alcohol out of the jar and into a stoppered bottle when the burner is not being used. Another way is to wrap the wick tightly with aluminum foil. A glass jar about the same size or smaller than the original jar, but with a larger mouth, when placed over the homemade alcohol burner, will also prevent evaporation.

Perhaps the most common source of heat used in the classroom is the electric hot plate. One of the problems in using a hot plate is that the intensity of the heat usually cannot be controlled. There are hot plates where the heat intensity can be controlled by a dial, but these hot plates are more expensive. As a safety measure the hot plate should be placed on an asbestos pad when being used.

Recently, scientific supply houses, and also stores like Sears, Roebuck and Company, have begun to sell a comparatively inexpensive portable Bunsen

burner. This burner consists of a small tank of propane or butane gas and a piece of metal shaped like a Bunsen burner that is screwed onto the tank. The tank rests upon a stand, which makes the burner quite stable. The heat produced by the burning gas is very intense, and a tank will produce a flame that lasts for several hours. After the complete outfit is purchased, the only additional minor expense required is periodic replacement of the tank when the supply of gas in it is used up.

COMMERCIAL SUPPLIES AND EQUIPMENT

Teachers and science educators have developed great resourcefulness in improvising and constructing all kinds of materials to provide for science experiences in the classroom. There are many commercial materials, however, that will still have to be purchased if the science program is to be effective. Dry cells, wire, porcelain sockets, lamps, assorted magnets, compasses, lenses, prisms, Petri dishes, rubber stoppers with and without holes, glass rods, glass tubing, and various chemicals are only a few of the many items needed when teaching science in the elementary school.

Furthermore, even when substitutes can be improvised, it is often essential to purchase the commercial equivalents. Although the children can construct a homemade barometer, it is equally important to have a commercial barometer in the classroom so that they can learn how to read and use barometers accurately. This fact also is true for the study of temperature and thermometers. If the children can see and actually use Centigrade and Fahrenheit thermometers, it is much different from constructing reasonable facsimiles. A homemade electric switch is fine, but children will get a clearer picture of how a switch actually operates in the home when a push-button buzzer or bell is also available for examination. The construction of a simple motor will help the children better understand the science concepts involved in the construction and operation of the motor and, as such, is a perfectly warranted activity. But a simple commercial St. Louis motor will enable the children to gain a greater insight into the operation and purpose of the motor, and at the same time provide for further exploration and additional activities of an advanced nature.

Most of the commercial supplies and equipment recommended for use in elementary science are relatively inexpensive. However, if a school system is organizing a planned science program, complete with materials, the initial outlay required to obtain basic materials for the program will be rather large. It would be understandable, then, that at first only the most essential items would be produced, and that the numbers of each kind of item available for use in the classroom might necessarily be limited. But as long as a definite science budget is provided each year, even though modest, teachers can plan and order cooperatively and build up a good-sized inventory of needed materials in a comparatively short time. In this way a wide variety of materials can be made available to the children, and in sufficient quantities so that they all can have an opportunity to work with the materials.

Some of the more specialized pieces of equipment are also highly

desirable in the elementary school. These items include the microscope, microprojector, barometer, planetarium, and telescope. To plan for the purchase of such equipment needs careful consideration because the items are expensive and should be bought only if there is definite provision for the equipment's use in the classroom. Although most budgets are not large enough to accommodate the purchase of such equipment, the teachers should nevertheless try to acquire these items, even if it is done gradually and with a great deal of planning. Incidentally, this case is an example where the Parent-Teachers Association can be very helpful. When they are made aware of the need for such equipment and the learning values the children will accrue from its use, contributions will often be made for the purchase of the needed items.

SELECTING AND ORDERING SUPPLIES AND EQUIPMENT

Most elementary schools have a budget each year for ordering general supplies and equipment. Very seldom, however, do these schools have a separate science budget. Requests for science materials are usually given equal consideration with requests for other materials, and then a proportion of the general budget is allocated for science. The usual policy is for the school to prepare requisitions for supplies and equipment in the early spring to be available for the succeeding year. Teachers are given, or asked to prepare, order forms for needed materials. The teachers may work either individually or in groups as committees when preparing the forms. The forms are then given to the principal, who goes over the lists and determines how much of the material can be purchased, depending upon the budget. The principal sends a total list for the school to the superintendent's office, where the lists from all the schools are compiled into a master list. Orders for materials are sent to various supply houses, and, when the materials arrive, they are separated so that each school receives the materials that it ordered. This procedure is the same when a school has a definite science budget, except that in this case the teachers now know exactly how much money they can spend. Also, when there is a specific budget for science materials, there is a greater likelihood that more money will be allocated for science and that it will be increased when necessary.

By knowing that the order will be due in the spring, it might be helpful for the teacher to keep a record during the year of materials to be replaced and of additional materials needed or wished. When preparing the list in the spring, the teacher should consult the catalogs of the scientific supply houses. Careful attention is necessary to avoid mistakes in ordering. Each catalog lists different sizes and qualities of the same article. Also, it is necessary to know the exact use for which the article is intended. If the teacher is in doubt, she should ask the science consultant or a high school science teacher to check the list. For clarity in ordering, the teacher must include the name of the item, together with any special characteristics such as size, dimensions, and so forth, the quantity desired, the catalog number of the item, and the cost.

When a school system has a planned and structured science program, a

committee for ordering materials would be very helpful. There could be small committees for each school, and possibly a central committee for the school system. The committee could take inventory, receive requests from the teachers, prepare the school science order, and work with the principal in determining what materials could be obtained within the means of the budget. It would be wise for the committee to consist of members with a comparatively good science background and knowledge of science materials. The science consultant or supervisor, if there is one, could be of great service and should assume a leadership role with the committee. If there is no supervisor available, a high school science teacher can be consulted instead.

Purchasing materials from local sources has advantages and drawbacks. On one hand, the service is quick, and it is a good policy to patronize local merchants. On the other hand, there is the possible risk that much time and effort will be required to locate the items. Many small orders may have to be prepared rather than one uncomplicated, large order. To please all the merchants, purchases would either have to be rotated periodically or bids requested. The question of whether to make local purchases is usually decided individually by the school systems. Many use local sources during the year when drawing from petty cash to buy small items that are needed in an emergency or that must be purchased only at the last minute.

SUGGESTED LIST OF SUPPLIES AND EQUIPMENT

Any suggested list of supplies and equipment is usually arbitrary. As stated previously, the materials needed by a school system will depend upon the kind of science program the school system has. If the science program is built around a single textbook series, a list of materials needed for the experiments and other activities described in the books will be the materials list for the program. Actually, many publishers of such textbooks have already prepared such lists and will mail them to schools upon request.

When the science course is structured and has a specific course of study, the materials needed will depend upon the activities suggested in the course of study. In such cases the list can become quite extensive. It might be profitable to divide the materials into more than one category. For example, there might be one list of materials considered basic or essential to the course. A second list might contain materials that would help to enrich further the children's learning. The materials in the second list could be purchased whenever sufficient funds were available.

A list of supplies and equipment usually needed in active, on-going science programs is given in Table 7–1. For convenience, the supplies and equipment are combined and appear alphabetically under an alphabetical listing of separate science topics or general equipment categories. A list of miscellaneous materials commonly found in the home is also included. The supplies and equipment can be ordered from any general scientific supply house. Many items can also be obtained locally from hardware stores, drug stores, variety stores, groceries and supermarkets, and toy shops.

TABLE 7–1. Supplies and Equipment for Elementary Science

AIR AND WEATHER	
Anemometer	Rain gauge
Barometer, aneroid	Tubes, barometer
Fan, electric	Weather forecast indicator
Hygrometer, wet and dry	
ANIMALS	
Animal cages	Insect nets
Aquarium	Wire mesh, ½ inch
Dip nets	Wire screen
Insect cages	
ASTRONOMY	
Balls, assorted	Lamp, gooseneck
Flashlight	Planetarium, inexpensive
Globe, terrestial	Telescope and tripod
CHEMICALS	
Alcohol, denatured or wood	Manganese dioxide
Ammonia	Mercury, metal
Ammonium dichromate	Nitric acid, dilute
Baking soda (sodium bicarbonate)	Paraffin
Carbon tetrachloride	Plaster of Paris
Copper sulfate, crystals	Salt, table
Food coloring, assorted	Splints, wood
Hydrochloric acid, dilute	Starch
Hydrogen peroxide, 3 percent	Sulfur, powdered
Iodine, tincture	Sulfuric acid, dilute
Limewater (calcium hydroxide)	Vinegar
Litmus paper, red and blue	Washing soda (sodium carbonate)
CORK AND RUBBER	
Balloons, rubber	Stoppers, rubber, one-hole
Dam, rubber	Stoppers, rubber, two-hole
Stoppers, cork, assorted	Tubing, plastic, assorted
Stoppers, rubber, solid	Tubing, rubber, assorted
ELECTRICITY	
Bell, electric	Generator, electric, hand powered
Buzzer, electric	Motor, St. Louis type
Copper strips, 1 inch × 4 inches	Porcelain sockets, screw base, for flash-light bulb
Copper wire, insulated, #18 or #20	Switches, knife
Copper wire, insulated, #28	

Electricity, Continued

Dry cells, #6
Flashlight and batteries
Flashlight bulbs, screw base, 1½ and 3 volt
Fuses
Switches, push button
Telegraph set
Zinc strips, 1 inch × 4 inches

Glassware

Beakers, Pyrex, assorted
Cylinders, graduated, assorted
Droppers, medicine
Evaporating dishes, porcelain
Flasks, Erlenmeyer, assorted
Flasks, Florence, assorted
Funnels, short stem
Jars, battery
Rods, assorted thicknesses
Test tubes, Pyrex, assorted
Thistle tube
Tubing, assorted widths

Heat, Fire, and Fuels

Alcohol burner
Asbestos mat
Ball-and-ring apparatus
Boiler, double
Candles
Canned heat
Chimneys, lamp
Compound bar apparatus
Convection box
Gas burner, portable
Hot plate, electric
Matches, safety
Tea kettle
Thermometer, clinical
Thermometers, Centigrade
Thermometers, Fahrenheit
Thermometer, outdoor
Wire, copper
Wire, iron

Ironware and General Supplies

Filter paper, assorted sizes
Forceps
Ring stand and rings
Spatula, stainless steel
Test tube clamps
Test tube holders
Test tube rack
Tongs, crucible
Tripod
Wire gauze, plain and asbestos center

Light

Blueprint paper
Cellophane, assorted colors
Color top
Flashlight
Lamp, gooseneck
Lenses, concave and convex
Mirror, concave and convex
Mirrors, plane
Prism, equilateral

Machines and Friction

Balance, platform, and weights
Balances, spring, assorted
Gyroscope
Rope, clothesline and cord
Rulers
Scale, bathroom

Machines and Friction, Continued

Meter sticks	Wood boards, assorted lengths
Pulleys, single and double	Yardsticks

Magnetism

Blueprint paper	Magnets, cylindrical, Alnico
Compasses, magnetic	Magnetic needle, mounted
Iron filings, fine	Nails, large, assorted
Lodestone	Steel needles, knitting
Magnets, bar	Steel needles, sewing
Magnets, horseshoe	Tacks, iron
Magnets, U-shaped	

Miscellaneous

Aluminum foil	Paints and paint brushes
Baby bottles, Pyrex	Paper clips
Bags, paper and plastic	Ping-pong balls
Bottles, assorted	Pins
Boxes, cigar and wood	Pots and pans, aluminum and Pyrex
Cans, assorted	Potholder
Cardboard	Razor blades
Cement, household	Rubber bands, assorted
Clothespins, spring type	Screws, assorted
Clay, modeling	Sealing wax
Coat hangers, thin wire	Soda straws
Cotton, absorbent	Sponges, assorted
Funnels, metal and plastic	Steel wool
Glue and paste	String, assorted
Hose, garden	Tacks, assorted
Jars, glass, assorted	Thread, assorted
Marbles	Utensils (forks, knives, spoons)
Nails, assorted	Wood, strips and boxes
Nuts and bolts	

Plants

Bouillon cubes	Plants, assorted
Bulbs, assorted	Seeds, assorted
Gelatin	Slides, microscope
Germinating boxes	Soil, fertile
Lens paper, microscope	Soil-testing kit
Microscope	Sprinkling can
Nutrient agar	Terrarium
Petri dishes	Trowel

Sound

Musical instruments, toy	Tuning forks, set
Telephone receiver and transmitter	Wire, music or fine steel

Static Electricity	
Balloons	Polyethylene bags
Cat fur	Rubber rods, hard
Electroscope	Silk cloth
Glass rods	Thread
Pith balls	Wool cloth

Tools	
Cork borer	Pliers, with cutters
Drill	Sandpaper
File, flat	Saw
File, round	Scissors
File, triangular	Screw drivers
Hacksaw and blades	Soldering iron and solder
Hammer, claw	Tin snips
Hammer, geological	Vise
Jackknife	Wrench
Knife (not folding)	

SOURCES OF GENERAL SUPPLIES AND EQUIPMENT

The following are some companies that provide general supplies and equipment for all areas of science. This list includes companies who provide apparatus, instruments, ironware, glassware, rubber and plastic materials, chemicals, models, live and preserved specimens, charts, and so forth. Some of these companies also provide more specialized materials as well. All the companies will send the school a catalog upon request.

1. Cambosco Scientific Co., 37 Antwerp St., Brighton 35, Mass.
2. Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.; and 79 Amherst St., Cambridge A Station, Boston, Mass.; and 237 Sheffield St., Mountainside, N.J.
3. Central Scientific Co. of California, 6446 Telegraph Rd., Los Angeles 22, Calif.
4. Central Scientific Co. of Canada, 146 Kendal Ave., Toronto 4, Ont., Canada.
5. Chicago Apparatus Co., 1735–43 N. Ashland St., Chicago 22, Ill.
6. Fisher Scientific Co., 711–732 Forbes St., Pittsburgh 19, Pa.; and 635 Greenwich St., New York 14, N.Y.
7. New York Scientific Co., 28 W. Thirtieth St., New York, N.Y.
8. E. H. Sargent and Co., 4647 W. Foster Ave., Chicago 30, Ill.
9. Southern Scientific Co., Atlanta 3, Ga.
10. Standard Scientific Corp., 34 W. Fourth St., New York, N.Y.
11. Stansi Scientific Co., 1231 N. Honore St., Chicago 22, Ill.
12. United Scientific Co., 204 Milk St., Boston 9, Mass.
13. The Welch Scientific Co., 7300 Linder Ave., Skokie, Ill.

SOURCES OF SPECIALIZED SUPPLIES AND EQUIPMENT

The following are only a few of the companies that provide specialized supplies and equipment; the specialties of each company follow its address. There are usually local companies in each city or town that also offer specialized materials. All of the listed companies will send the school a catalog upon request.

1. Allied Radio Corporation 833 N. Jefferson Blvd. Chicago 7, Ill.	Radio and electronic equipment, meters, etc.
2. Carolina Biological Supply Co. Elon College, N.C.	Biological supplies and equipment, living and preserved specimens, charts, models, etc.
3. Castolite Co. Woodstock, Ill.	Plastics for molding and embedding.
4. Central Scientific Co. 1700 Irving Park Rd. Chicago 13, Ill.	Hobby kits on electronics, geology, light, and weather.
5. Denoyer-Geppert Co. 5235–5239 Ravenswood Ave. Chicago 40, Ill.	Biological charts, models, etc.
6. Difco Laboratories, Inc. Detroit 1, Mich.	Media for growing cultures, staining reagents, etc.
7. Eastman Kodak Co. Rochester, N.Y.	Photography supplies and equipment.
8. Edmund Scientific Corp. Barrington, N.J.	Science project kits, teaching aids in astronomy, optics, magnets, weather.
9. General Biological Supply House 8200 S. Hayne Ave. Chicago 20, Ill.	Biological supplies and equipment, living and preserved specimens, charts, models, etc.
10. Heath Co. Benton Harbor, Mich.	"Do-it-yourself" electronic kits.

11. Industrial America, Inc. Merchandise Mart Plaza Chicago 54, Ill.	Hobby kits on light, weather, minerals, electronics, and physiology.
12. Los Angeles Biological Laboratories 2977 W. Fourteenth St. Los Angeles, Calif.	Biological supplies and equipment, living and preserved specimens, charts, models, etc.
13. Models of Industry, Inc. 2100 Fifth St. Berkeley, Calif.	Kits for earth science, weather, magnets, electricity, optics, and industrial processes.
14. A. J. Nystrom and Co. 3333 Elston Ave. Chicago 18, Ill.	Biological models, charts on elementary science.
15. Science Associates P.O. Box 216 194 Nassau St. Princeton, N.J.	Special teaching aids for astronomy, weather, light, and earth sciences.
16. Science Electronics, Inc. P.O. Box 237 Huntington, N.Y.	"Breadboard" type kits for teaching radio, electricity, and electronics.

SCIENCE KITS

Commercial science kits are boxes or chests of science materials assembled and sold by various scientific supply houses. The kits are especially designed for the elementary school for use in any grade. They are extremely popular and are welcomed by the busy principal or superintendent, who does not have time to order a wide variety of items from different catalogs; he can merely purchase one item from one supply house. The kits are usually found in schools with no planned or structured science program, where the administrator would like to encourage the teachers to conduct science learning in the classroom. The kits are also welcomed by teachers who have a weak background in science and science materials.

The boxes or chests are specially built, are quite sturdy, and have handles so that they can be carried easily from room to room; they pose no storage problem. They contain a variety of materials, often almost exclusively in the area of physics or physical science. These materials are useful in teaching science, and are materials that the teacher could not ordinarily obtain, make, or improvise. Included in the kit is a booklet of suggested experiments and demonstrations that either the teacher or the children can do.

There has been much discussion about the value of commercial science kits. There are definite advantages in using these kits, but there are strong disadvantages as well. The favorable factors include those factors listed

above. Also, replacements, and even additions, to the kit can be purchased from the company manufacturing it. Where there is no planned or structured program, and little or no provision is made for science materials, the kit can be very helpful to the teacher.

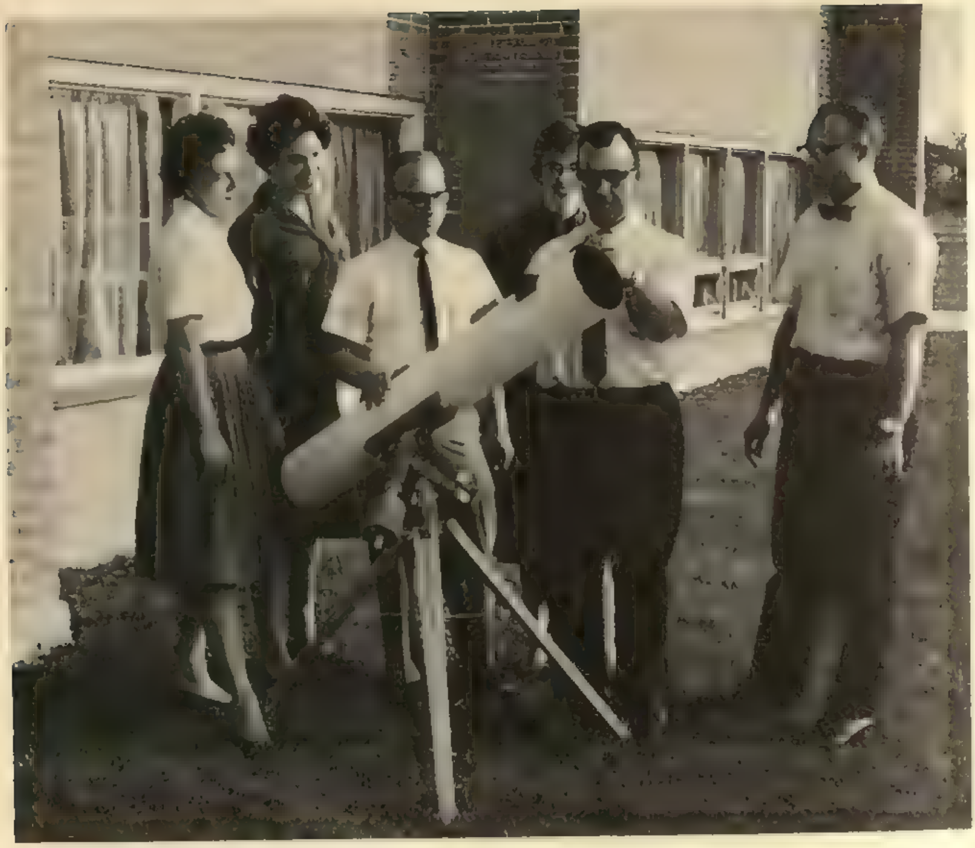
On the other hand, such kits cannot take the place of a well-defined science program with suggested activities, and with materials selected specifically to conduct these activities. Furthermore, although the kits can be used wisely and well, many teachers tend to become overdependent upon the kits, and they confine their activities only to those activities suggested in the accompanying booklet. Some teachers follow the booklet so rigidly and do the experiments in such a stereotyped fashion that the result is often a "cookbook" type of science teaching. Because the supplies in the kit are predominantly in the area of physics or physical science, the teachers are likely to neglect other important areas of science. In some kits the cost of the items is more than the cost would be if the items were purchased separately. Finally, although replacements can be ordered, often the teachers fail to do this ordering. Unless the principal or a designated teacher makes a periodic inventory of the contents of the kit, the broken or missing parts are not replaced, thus making the kit ineffective. After a certain point it is impossible to use the kit, and the kit is either neglected or discarded.

Many schools with well-organized science programs make their own kits. These kits differ from the commercial kits in that there are many homemade kits, each containing a variety of materials designed to teach concepts in only one topic or area in science. In this way there would be kits on sound, light, color, expansion and contraction, magnets, electromagnets, electricity, weather, the earth and the sun, earth science, and so forth. Often suggested activities, together with instructions, are included in the kit. Sometimes, for those teachers who are inexperienced in science, a list of the equipment is also enclosed, accompanied by drawings or pictures of special equipment with which the teacher might be unfamiliar.

So many of these homemade kits use shoe boxes to hold the materials that they are usually called "shoe-box kits." Another common name is "science-concept boxes." Some schools have sturdier boxes made, either by local carpenters or by school personnel. All the homemade kits are uniform, easy to pick up and return, and easy to store. This method is one way of supplying materials to the teachers, either when the budget is limited or the storage facilities in the classroom are minimal. The chief advantage of these homemade kits is that their contents can be geared to the objectives of the school science program and to the suggested activities that are a part of the program.

ACQUAINTING TEACHERS WITH UNFAMILIAR EQUIPMENT

As the schools purchase and accumulate science materials, it is essential that all the teachers become thoroughly familiar with the purpose, use, and care of these materials. Many teachers are reluctant to conduct experiments or demonstrations when they are unfamiliar with the equipment. In such



Acquainting teachers with unfamiliar equipment.

cases an orientation program can be very helpful. This program may be part of an in-service workshop designed to acquaint the teachers with the basic science information selected for the science program and with the activities that can be used to achieve the purposes of the program. It may also consist of a short series of group meetings, where the materials are displayed, their purpose and use explained, and the teachers given an opportunity to handle the materials and become adept at working with them.

At the same time the teachers should be informed of the precautions to be taken when using certain equipment. Instructions can be given about how to handle and store glassware, work with glass tubing, pour acids, and manipulate fragile apparatus. The teachers can be forewarned of certain measures they can take to prevent damage to materials. For example, when creating a short circuit by placing a piece of metal across two bared parts of the wires in an electric circuit, or by touching the bared parts together, it should be pointed out that the teacher or children must "short" the circuit for a very few seconds only. Otherwise the dry cell will quickly burn out. When storing chemicals, ammonia water should be placed as far away as possible from acids, especially hydrochloric acid. If not, a fine white salt will be formed (with hydrochloric acid the product is ammonium chloride)

that will cover and possibly affect ironware, contaminate loosely sealed chemicals, coat bottles, and cause the labels to disintegrate.

The teachers should also be warned about the care they must take to avoid accidents, both to themselves and the children, when working with science materials. Many times schools have banned certain materials or activities because accidents that could have been prevented happened in the classrooms. In some cases, when children have received burns, the use of open flames—even from candles—has been prohibited in the classroom. Bites or scratches by animals have resulted in the banning of all animals from the school.

The teacher must thoroughly inculcate in the children good safety habits until these habits become automatic. The children should be taught to avoid careless handling of tools, sharp or pointed objects, all kinds of glassware, and sources of heat. The teacher must be extremely careful whenever electrical appliances, such as lamps or hot plates, are used. Wiring should be examined for frayed or cracked insulation. Children should be warned never to touch an electric switch, cord, or appliance with wet hands. When electric appliances are not being used, they should be disconnected. Definite rules must be established about the handling and treatment of pets in the classroom. As a safety measure, a bucket of sand or water should be nearby for emergencies, and a fire extinguisher and first-aid kit should be easily accessible.

STORING SUPPLIES AND EQUIPMENT

All teachers should have in their classrooms certain essential supplies and equipment, especially those items used regularly throughout the year. In an on-going, active science program, however, there will be many items that are only used periodically. Special pieces of equipment and a wide variety of chemicals are also included. All these materials must be stored. Ideally, each school should have its own central supply room for science materials. If it is not possible to have such a room, perhaps some space from an already existing supply room can be utilized. In an emergency, storage cabinets could be purchased and placed in a convenient location.

It might be helpful to store the equipment by science topics or areas. Thus, one shelf might have materials for the study of machines, another one for electricity, and so on. The shelves should be labeled for easy identification and also to keep the materials arranged in an orderly manner. Sometimes a list of the materials is attached to each shelf, together with drawings or pictures of items that are likely to be unfamiliar to the teachers. Glassware should be kept separately from ironware. Chemicals must be stored separately from apparatus; they are usually arranged alphabetically. The chemicals should be kept in tightly closed containers and labeled clearly and correctly. If children are allowed to obtain materials from the supply room, it would be wise to place strong acids and bases, and other chemicals that are poisonous or harmful, high on the shelves.

A science-minded teacher should be placed in charge of the supply room or storage cabinets. This person can keep an inventory of all the materials,

listing in each case the name of the item, the quantity, the size, where it was purchased, the catalog number, and the price. The materials would be checked periodically for needed repairs or replacement. Moreover, provision should be made for checking materials in and out. This checking is always a problem because much time can be wasted in trying to locate materials that some teacher is either using or has forgotten to return to the supply room. An effective method is to have a notebook in the supply room. Each teacher could write down the items that were borrowed, the teacher's name, the date the items were borrowed, and the date returned. If a piece of equipment is broken or a chemical is used up, it would be helpful if the person in charge of the supply room were informed immediately.

Science Facilities in the Classroom

If science is to achieve its proper place in the elementary school curriculum, with effective teaching and learning of science going on in the classroom, adequate facilities are needed. Each classroom must be self-contained, with sufficient materials and facilities available for both the teacher and children to perform satisfactorily the science learning activities.

All elementary school classrooms need a table where experiments and demonstrations can be conducted. Many teachers have learned—to their distress when mishaps occur—that the teacher's desk does not make a suitable demonstration table. It would be ideal to have a small, permanent laboratory table in some, if not all, of the rooms, equipped with gas, hot and cold running water, and electrical outlets. Several scientific supply houses now sell movable laboratory tables. These tables are on rollers and can be moved within the room, or from room to room. They have chemical resistant tops, small stainless steel sinks with a pump faucet, a supply of fresh water, and provision for drainage of waste water into special containers. An electrical receptacle with more than one outlet, and with an extra long cord, is attached to the desk. Inside the table are adjustable shelves. The tables can be purchased with or without equipment and/or science kits.

These movable tables are becoming more popular in the elementary school. They are rather expensive, however, and it is not easy to acquire them even with help from National Defense Education Act, Title III, funds. Consequently, most elementary schools have one, or very few, of this kind of table. Although the tables can be moved from room to room, they often are found in the rooms of the science-minded teachers, remaining there the entire year. These tables are quite heavy and are rather difficult to lift or carry. In older, two-story elementary school buildings the tables usually are confined to the level on which they are originally placed.

Many schools are using improvised, movable laboratory tables, constructed by local or school personnel. The tables are made of wood with rollers attached to the bottom. One end is open, without the sliding doors found in commercial tables, and there is usually one fixed shelf. Inlaid

A science corner in the classroom.

linoleum is used instead of a chemically resistant top. There is no sink or pump faucet with a supply of water. A hole bored through the top, to one side, allows a funnel to be inserted, and a rubber or plastic hose attached to the end of the funnel connects to a pail inside the desk. Fresh water must be brought into the classroom with a bucket or another container. An electrical receptacle is attached to the table. These tables are obviously much less ornate and do not have some of the desirable features of the commercial tables, but they are equally useful. Furthermore, for the same amount of money as required to purchase one commercial table, several classrooms can be equipped with improvised tables. It is interesting to note that many enterprising teachers have been using tables of this kind for some time; they are made from old desks, dressers, and bureaus.

Every classroom should also have at least one table where the children can do experiments, work on projects, or display materials. Also, there should be facilities for storing supplies and equipment. Teachers seriously need storage space for bottles, beakers, flasks, ring stands, supports, clamps, tongs, wire, flower pots, tools, simple chemicals, and other materials. There are several ways in which storage space can be provided. Cabinets or cases are a possibility. Wall counters, with storage space and shelves below, installed along the window side of the room are another possibility. The tops of the counters can be used to hold plants, germinating beds, aquariums, or terrariums. They may also serve to display models, specimens, and completed projects. Where school funds are limited, open shelves can be constructed, and the tops covered with inlaid linoleum.

Free and Inexpensive Materials

A LARGE number of industrial organizations supply excellent free or inexpensive science materials for use in the elementary classroom. Many of the firms either have special personnel or employ the services of scientists and educators to develop these materials. The materials include charts, maps, pictures, leaflets, booklets, films, filmstrips, phonograph records, and sometimes small quantities of materials. Most of the printed materials are well written, geared for the elementary school, and contain a minimum of advertising. These materials can be obtained by writing directly to the organizations that supply them. Because almost all the materials contain some advertising, it might be advisable for the teacher to check with the school administration about policy in allowing materials containing advertising to be given to the children.

REFERENCES

To list all the organizations that provide free and inexpensive materials would be impossible. However, the following are some of the publications that tell where such materials may be obtained. Prices of these publications, if any, are subject to change, of course.

1. Beuschlein, Muriel. *Free and Inexpensive Materials for Teaching Conservation and Resource Use*. National Association of Biology Teachers, P.O. Box 2073, Ann Arbor, Mich., 1954.
2. Beuschlein, Muriel, and James Saunders. *Free and Inexpensive Teaching Materials for Science Education*. Chicago Schools Journal Supplement, Vol. 34, No. 5, 6, 1953. (Available as a reprint) Chicago Teachers College, Chicago, Ill.
3. *Educator's Guide to Free Films*. Educator's Progress Service, Randolph, Wis. $9.00.
4. *Educator's Guide to Free Filmstrips*. Educator's Progress Service, Randolph, Wis. $6.00.
5. *Educator's Guide to Free Science Materials*. Educator's Progress Service, Randolph, Wis. $7.25.
6. Fowlkes, John G., *et al. Elementary Teachers' Guide to Free Curriculum Materials*. Educator's Progress Service, Randolph, Wis. $7.50
7. *Free and Inexpensive Learning Materials*. Division of Surveys and Field Services, George Peabody College for Teachers, Nashville, Tenn., 1960. $1.50.
8. *General Motors Aids to Educators*. General Motors Corp., Willow Run, Mich.
9. Holland, C. *Free and Inexpensive Teaching Aids for High Schools*. National Association of Secondary School Principals, NEA, 1201 Sixteenth St., N.W., Washington 6, D.C., 1949. $1.00.

10. Miller, Bruce. *Free and Inexpensive Instruction Aids.* Bruce Miller Publishers, P.O. Box 369, Riverside, Calif.
11. Moore, Shirley, and Judith Viorst (eds.). *Wonderful World of Science.* Bantam Books, Inc., 271 Madison Ave., New York 16, N.Y., 1961. 50¢.
12. Phillips, Brose. *Index to Free Teaching Aids.* Free Teaching Aids Co., Harrisburg, Ill.
13. Salisbury, Gordon, and Robert Sheridan. *Catalog of Free Teaching Aids.* P.O. Box 943, Riverside, Calif. $1.50.
14. *Science Service Aids to Youth.* Science Service, 1719 N St., N.W., Washington 6, D.C.
15. *Sources of Free and Inexpensive Materials in Health Education.* Curriculum Laboratory, Teachers College, Temple University, Philadelphia 22, Pa., 1954. 25¢.
16. *Sources of Free and Low-Cost Materials.* U.S. Department of Commerce, Civil Aeronautics Commission, Office of Aviation Development, Washington 25, D.C.
17. *Sponsors Handbook.* Science Service, 1719 N St., N.W., Washington 6, D.C. 1957. 25¢.
18. Weisinger, M. *1001 Valuable Things Free.* Bantam Books, Inc., 271 Madison Ave., New York 16, N.Y., 1957. 50¢.
19. *Westinghouse Teaching Aids.* Westinghouse Electrical Corp., School Service, 306 Fourth Ave., Pittsburgh 30, Pa.

Printed Materials

MANY kinds of printed materials are necessary for the successful operation of an elementary science program. Teachers must avail themselves of the large number of professional publications that will help them develop or reorganize the program, and guide them in teaching science more effectively in the classroom. They should be able to consult a wide variety of source books that describe experiments, demonstrations, and other science activities. Children need textbooks, trade books, and reference books. There are also a number of bulletins and pamphlets that are specifically printed to help both teachers and children.

SOURCES ON THE TEACHING OF SCIENCE

All of the following materials are designed to help the elementary school teacher in developing science programs, planning daily work, and increasing teaching effectiveness in science. For convenience, these materials have been listed under three separate classifications: (1) books, (2) bulletins, and (3) journals and magazines. Latest names and addresses are given, in cases in which the original publisher has merged with another.

Printed materials are necessary for learning science.

Books on the Teaching of Elementary Science

1. Blough, Glenn O., and Julius Schwartz. *Elementary School Science and How to Teach It*. New York: Holt, Rinehart & Winston, 1964. 655 pp.
2. Burnett, R. Will. *Teaching Science in the Elementary School*. New York: Holt, Rinehart & Winston, 1953. 529 pp.
3. Craig, Gerald S. *Science for the Elementary School Teacher*. Boston: Ginn, 1958. 894 pp.
4. Croxton, W. C. *Science in the Elementary School*. New York: McGraw, 1937. 454 pp.
5. Freeman, Kenneth, *et al. Helping Children Understand Science*. New York: Holt, Rinehart & Winston, 1954. 314 pp.
6. Greenlee, Julian. *Better Teaching Through Elementary Science*. Dubuque, Iowa: C. Brown, 1954. 204 pp.
   ———. *Teaching Science to Children*. Dubuque, Iowa: C. Brown, 1955. 195 pp.
7. Hubler, Clark. *Working with Children in Science*. Boston: Houghton, 1957. 425 pp.
8. Kambly, Paul E., and John E. Suttle. *Teaching Elementary School Science*. New York: Ronald, 1963. 492 pp.
9. Lewis, June E., and Irene C. Potter. *The Teaching of Science in the Elementary School*. Englewood Cliffs, N.J.: Prentice-Hall, 1961. 381 pp.

10. Navarra, John G., and Joseph Zaffaroni. *Science Today for the Elementary School Teacher.* New York: Harper, 1960. 470 pp.
11. National Elementary Principal. *Science for Today's Children.* Thirty-second Yearbook, Vol. 33, No. 1, September, 1955. Department of Elementary School Principals, N.E.A., 1201 Sixteenth St., N.W., Washington 6, D.C. 311 pp.
12. National Society for the Study of Education. *A Program for Teaching Science.* Thirty-first Yearbook, Part I. Chicago: U. of Chicago, 1932. 370 pp.
13. ———. *Science Education in American Schools.* Forty-sixth Yearbook, Part I. Chicago: U. of Chicago, 1947. 306 pp.
14. ———. *Rethinking Science Education.* Fifty-ninth Yearbook, Part I. Chicago: U. of Chicago, 1960. 344 pp.
15. Tannenbaum, Harold E., and Nathan Stillman. *Science Education for Elementary School Teachers.* Rockleigh, N.J.: Allyn & Bacon, 1960. 399 pp.
16. Wells, Harrington. *Elementary Science Education.* New York: McGraw, 1951. 333 pp.

Science Education Bulletins

1. Ashley, Tracy H., *et al. An Administrator's Guide to the Elementary School Science Program.* Association of Public School Systems, 525 W. 120th St., New York, N.Y. 30 pp.
2. Aylesworth, Thomas G. *Planning for Effective Science Teaching.* American Education Publications, Education Center, Columbus 16, Ohio, 1963. 96 pp.
3. Blough, Glenn O. *It's Time for Better Elementary Science.* National Science Teachers Association, 1201 Sixteenth St., N.W., Washington, D.C., 1958. 48 pp.
4. Craig, Gerald S. *Science in the Elementary School: What Research Says to the Teacher Series.* Department of Classroom Teachers, N.E.A., 1201 Sixteenth St., N.W., Washington 6, D.C., 1957. 33 pp.
5. Dunfee, Maxine, and Julian Greenlee. *Elementary School Science: Research and Practice.* Association for Supervision and Curriculum Development, N.E.A., 1201 Sixteenth St., N.W., Washington 6, D.C., 1957. 67 pp.
6. Fitzpatrick, F. L. (ed.). *Policies for Science Education.* Teachers College, Columbia University, New York, N.Y., 1960.
7. *Improvement of the Teaching of Science and Mathematics in the Elementary Schools.* De Pauw University, Greencastle, Ind., 1958. 42 pp.
8. *Laboratories in the Classroom: New Horizons in Science Education.* Science Materials Center, 59 Fourth Ave., New York 3, N.Y., 1960. 96 pp.
9. *The New School Science.* American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington 5, D.C., 1963. 92 pp.

10. *Strengthening Science Teaching in Elementary Schools.* Illinois Curriculum Program, Subject Field Series, Bulletin No. C-3. Superintendent of Public Instruction, Springfield, Ill., 1960. 184 pp.
11. Ulry, Orval L. (ed.). *Science Courses of Study: A Compilation.* National Science Teachers Association, 1201 Sixteenth St., N.W., Washington 6, D.C., 1958. 27 pp.
12. Zaffaroni, Joseph. *New Developments in Elementary School Science.* National Science Teachers Association, 1201 Sixteenth St., N.W., Washington 6, D.C., 1963.
13. Zim, Herbert S. *Science for Children and Teachers.* Association for Childhood Education International, N.E.A., 1201 Sixteenth St., N.W., Washington 6, D.C., 1953. 53 pp.

Science Education Journals and Magazines

1. *Audubon Magazine.* National Audubon Society, 1130 Fifth Ave., New York 28, N.Y.
2. *Cornell Rural School Leaflets.* New York State College of Agriculture, Cornell University, Ithaca, N.Y.
3. *Science and Children.* National Science Teachers Association, 1201 Sixteenth St., N.W., Washington 6, D.C.
4. *The Grade Teacher.* Educational Publishing Co., Darien, Conn.
5. *The Junior Astronomer.* Benjamin Adelman, 4211 Colie Dr., Silver Spring, Md.
6. *Metropolitan Detroit Science Review.* Metropolitan Science Club, 4830 Grady St., Detroit 7, Mich.
7. *National Geographic Magazine.* National Geographic Society, 1146 Sixteenth St., N.W., Washington, D.C.
8. *Natural History.* American Museum of Natural History, Seventy-ninth St. and Central Park West, New York 24, N.Y.
9. *Outdoors Illustrated.* National Audubon Society, 1130 Fifth Ave., New York 28, N.Y.
10. *Popular Mechanics.* Popular Mechanics Co., 250 W. Fifty-fifth St., New York 17, N.Y.
11. *Popular Science.* Popular Science Publishing Co., 355 Lexington Ave., New York 19, N.Y.
12. *School Science and Mathematics.* Central Association of Science and Mathematics. 450 Ahnsip St., Menasha, Wis.
13. *Science Digest.* Science Digest, 250 W. Fifty-fifth St., New York 19, N.Y.
14. *Science Education.* National Association for Research in Science Teaching, University of Tampa, Tampa, Fla.
15. *Science News Letter.* Science Service, 1719 N St., N.W., Washington 6, D.C.
16. *The Science Teacher.* National Science Teachers Association, 1201 Sixteenth St., N.W., Washington 6, D.C.
17. *Science World.* Scholastic Magazines, 33 W. Forty-second St., New York 36, N.Y.

18. *Sky and Telescope.* Sky Publishing Corp., Harvard College Observatory, 60 Garden St., Cambridge 38, Mass.
19. *Skylights.* National Aviation Education Council, 1205 Connecticut Ave., N.W., Washington 6, D.C.
20. *Weatherwise.* American Meteorological Society, 3 Joy St., Boston 8, Mass.

GENERAL SOURCEBOOKS OF EXPERIMENTS AND DEMONSTRATIONS

There are already a tremendous number of books that can be used as sources for experiments and demonstrations in elementary science. More books are being printed daily, as the present interest in science continues to grow. Some books are general and suggest activities in several or all areas of science. Other books are restricted to individual science topics. Some are designed primarily for the teacher whereas others are written for the children on their level.

The following are some of the general sourcebooks of experiments and demonstrations, intended primarily for teacher use. Books on specific topics, for teachers and children, are listed at the end of each science chapter later on in this textbook.

1. Arey, Charles K. *Science Experiences for Elementary Schools.* New York: Teachers College, Columbia University, 1953. 98 pp.
2. Ashbaugh, B., and Muriel Beuschlein. *Things to Do in Science and Conservation.* Danville, Ill.: Interstate Printers, 1960.
3. Atkin, J. Myron, and R. Will Burnett. (1) *Air, Winds, and Weather;* (2) *Electricity and Magnetism;* (3) *Working with Animals;* (4) *Working with Plants* (four booklets of demonstrations and experiments). New York: Holt, Rinehart & Winston, 1958.
4. Baker, Tunis. *Baker Science Packet.* Baker Science Packets, 42 Carolin Rd., Upper Montclair, N.J.
5. Beauchamp, Wilbur L., and Helen J. Challand. *Basic Science Handbook K–3.* Chicago: Scott, 1961. 352 pp.
6. Beeler, Nelson F., and Franklyn M. Branley. *More Experiments in Science.* New York: Crowell, 1960. 176 pp.
7. Blough, Glenn O., and Marjorie H. Campbell. *Making and Using Classroom Science Materials in the Elementary School.* New York: Holt, Rinehart & Winston, 1954. 229 pp.
8. Comstock, Anna B. *Handbook of Nature Study* (24th ed.). Ithaca, N.Y.: Comstock Publishing Associates, 1957. 937 pp.
9. Cooper, Elizabeth K. *Science in Your Own Back Yard.* New York: Harcourt, 1960. 192 pp.
10. Herbert, Don. *Mr. Wizard's Science Secrets.* New York: Hawthorn, 1952. 264 pp.
11. ———. *Mr. Wizard's Experiments for Young Scientists.* New York: Doubleday, 1959. 187 pp.

12. Hone, Elizabeth, Alexander Joseph, and Edward Victor. *A Sourcebook for Elementary Science*. New York: Harcourt, 1962. 552 pp.
13. Hungerford, Harold R., and Robert E. Drew. *Teaching Elementary Science Without a Supervisor*. J. Weston Walch, Publisher, P.O. Box 1075, Portland, Me., 1959. 286 pp.
14. Laybourn, K., and C. H. Bailey. *Teaching Science to the Ordinary Pupil*. New York: Philosophical Library, 1957. 415 pp.
15. Lemming, Joseph. *The Real Book of Science Experiments*. New York: Doubleday, 1954. 224 pp.
16. Lynde, Carleton J. *Science Experiments with Home Equipment*. Princeton, N.J.: Van Nostrand, 1955. 244 pp.
17. ———. *Science Experiments with Inexpensive Equipment*. Princeton, N.J.: Van Nostrand, 1955. 280 pp.
18. ———. *Science Experiments with Ten-Cent Store Equipment*. Princeton, N.J.: Van Nostrand, 1955. 276 pp.
19. *Microscope Experiments for Elementary and High School*. El Monte, Calif.: Test Manufacturing Co., 1960.
20. National Science Teachers Association. "Science Teaching Today" series: Vol. 1. *Water;* Vol. 2. *Air;* Vol. 3. *Fuels and Fire;* Vol. 4. *Heat;* Vol. 5. *Magnetism and Electricity;* Vol. 6. *Sound;* Vol. 7. *Light and Color* (seven booklets of demonstrations and experiments). Publication Sales Section of N.E.A., 1201 Sixteenth St., N.W., Washington 6, D.C.
21. Nelson, Leslie W., and George C. Lorbeer. *Science Activities for Elementary Children*. Dubuque, Iowa: C. Brown, 1959. 153 pp.
22. New York City Board of Education. No. 1. *Magnetism and Electricity*; No. 2. *The Earth in Space;* No. 3. *Living Things;* No. 4. *Communication;* No. 5. *Weather;* No. 6. *Transportation;* No. 7. *Earth and Its Resources* (seven booklets of experiments and demonstrations). Board of Education, Division of Elementary Schools and Curriculum Development, 110 Livingston St., Brooklyn 1, N.Y. (Must be ordered by the principal or superintendent.)
23. New York State Education Department. *General Science Handbook, Part I*. 197 pp. *General Science Handbook, Part II*. 183 pp. *General Science Handbook, Part III*. 261 pp. (Three booklets of experiments and demonstrations.) New York State Education Dept., Bureau of Secondary Curriculum Development, Albany, N.Y. (Must be ordered by the principal or superintendent.)
24. Parker, Bertha M. *Science Experiences in the Elementary School*. New York: Harper, 1958. 272 pp.
25. Partridge, J. A. *Natural Science Through the Seasons*. New York: Macmillan, 1955. 522 pp.
26. Podendorf, Illa. *One Hundred and One Experiments*. New York: Grosset, 1960. 157 pp.
27. Stone, George K., and Lucy W. Stephenson. *Science You Can Use*. Englewood Cliffs, N.J.: Prentice-Hall, 1959. 383 pp.

28. Swezey, Kenneth M. *After-Dinner Science*. New York: McGraw, 1948. 182 pp.
29. ———. *Science Magic*. New York: McGraw, 1952. 182 pp.
30. ———. *Science Tricks for Fun*. Greenwich, Conn.: Fawcett, 1952. 144 pp.
31. *UNESCO Source Book for Science Teachers*. UNESCO Publications Center, 317 E. Thirty-fourth St., New York, N.Y., 1962. 250 pp.
32. Visner, Harold, and Adelaide Hechtlinger. *Simple Science Experiments for the Elementary Grades*. Palisade, N.J.: Franklin Publishing Co., Dept. 1, 1960. 232 pp.

SELECTING ELEMENTARY SCIENCE TEXTBOOKS

Textbooks play an important role in the elementary science program. As such, they should be used in the many ways suggested in Chapter 4, "Methods of Teaching Science," and not just for reading and discussion. Some school systems use only one science textbook series and develop the course of study around it. Other systems have a certain number of copies, ranging from two, three, or even four textbook series, in each grade. Their reason for using this method is that the grade placement of science topics varies among the various series and some topics are taken up in greater detail in one series than in another. The school systems find it easier to incorporate the use of textbooks in their science programs when multiple series are used.

When selecting textbooks, the teachers or committee should examine each series carefully. Several guides and checklists are available that will help in determining the final selection. The books should be attractive, of convenient size for handling, and with a durable cover and binding. They should have a table of contents, glossary, and index that the children can use quickly and easily.

The illustrations should be clear-cut and attractive. They should teach as well as illustrate, and their captions should include questions that stimulate thinking or the desire to read further. The experiments should be clear with directions that are easily understood; they should be the kind of experiments for children to do rather than for teachers to demonstrate. They should involve the use of simple materials so that the experiment can be repeated in the classroom if desired. The diagrams should be simple, accurate, easily understood, and labeled. The results of the experiment should not always be given immediately after the experiment is described.

The science content should be stated clearly and in an interesting manner, with the type large enough for convenient reading. The sentences should not be too long, and the content should be at the proper reading level. The material must be accurate and up-to-date, and related to the daily life and environment of the child. All the content should be part of a scope and sequence plan, with good balance between the physical and biological sciences. The books should, under no circumstances, ascribe to plants and animals human traits and personalities, or attribute to them a conscious purpose in changing their behavior when conditions change.

Each book should contain a relatively short number of well-developed units rather than a large number of scattered, fragmented topics. The units should be flexible enough to allow the exploration of situations that arise while the unit is in progress.

The books should stress the learning of basic science information, using technology to illustrate concepts. They should show the relationship of science to social studies, and include, where applicable, the areas of health, safety, and conservation. The science content and problems should be left open-ended, if possible, and be directed toward the promotion of problem solving and critical thinking, the development of scientific attitudes, and the inculcation of how scientists work. There should be provision for review for slow learners and opportunities for going further for fast learners. Finally, the books should be tested during and after their preparation.

The series should provide teachers' guides or manuals. These guides should list key science concepts for the teacher. They should suggest initiating activities and show how to coordinate the learning activities with the science content. They should include additional activities for slow and fast learners, and make recommendations for evaluation. They should append a bibliography of books, films, and filmstrips.

The following publishers offer elementary science textbook series, including teachers' guides, scope and sequence charts, and other teaching aids.

1. Allyn and Bacon, Inc., Rockleigh, N.J.
2. American Book Co., 55 Fifth Ave., New York 3, N.Y.
3. Beckly-Cardy Co., 1900 N. Narragansett, Chicago 39, Ill.
4. Ginn and Co., 72 Fifth Ave., New York 11, N.Y.
5. Harper and Row, 49 E. Thirty-third St., New York, N.Y.
6. D. C. Heath and Co., 285 Columbus Ave., Boston 16, Mass.
7. Holt, Rinehart & Winston, Inc., 383 Madison Ave., New York 17, N.Y.
8. J. B. Lippincott Co., E. Washington Sq., Philadelphia 5, Pa.
9. The Macmillan Co., 60 Fifth Ave., New York 11, N.Y.
10. Rand McNally & Co., 8255 Central Park Ave., Skokie, Ill.
11. Scott, Foresman & Co., 433 E. Erie St., Chicago 11, Ill.
12. Charles Scribner's Sons, 597 Fifth Ave., New York 17, N.Y.
13. L. W. Singer Co., 249 W. Erie Blvd., Syracuse 2, N.Y.

SUPPLEMENTARY ELEMENTARY SCIENCE SERIES

There is also a growing trend to publish supplementary science textbooks for the elementary school. As such, these books can be used as auxiliary textbooks and reference books in the classroom. The following are some of the series now being published.

1. *Basic Science Education Series.* Harper and Row, 49 E. Thirty-third St., New York, N.Y.

2. *Follett Beginning Science Books.* Follett Publishing Co., 1010 W. Washington Blvd., Chicago 7, Ill.
3. *How and Why Wonder Books.* Noble and Noble, Publishers, Inc., 67 Irving Place, New York 3, N.Y.
4. *Webster Classroom Science Series.* McGraw-Hill Book Co., 330 W. Forty-second St., New York, N.Y.

SOURCES OF SCIENCE TRADE BOOKS AND REFERENCE BOOKS

The following are some publications that contain bibliographies of science trade and reference books for use by teachers and children. Specific title references are listed at the end of each science chapter later in this textbook.

1. *A Bibliography of Books for Children.* Association for Childhood Education International, 3615 Wisconsin Ave., N.W., Washington, D.C. 134 pp.
2. *A Bibliography of Reference Books for Elementary Science.* National Science Teachers Association, 1201 Sixteenth St., N.W., Washington 6, D.C., 1960. 40 pp.
3. *A Bibliography of Science Books for Elementary School Children.* Bulletin, Vol. 28, No. 5. California State Department of Education, Sacramento, Calif., Sept. 1959. 115 pp.
4. *Children's Books for Nature Study.* Kansas City Naturalist, Vol. 3, No. 2. Kansas State Teachers College, Emporia, Kan., Dec., 1956. 16 pp.
5. *Children's Books for $1.25 or Less.* Association for Childhood Education International, 3615 Wisconsin Ave., N.W., Washington 5, D.C. 32 pp.
6. *Growing Up with Science Books.* Library Journal, 62 W. Forty-fifth St., New York 36, N.Y. 32 pp.
7. *The Science Book List for Children.* American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington 5, D.C., 1962. 201 pp.
8. *A Selected Bibliography in Elementary Science.* Board of Education of the City of New York, Bureau of Curriculum Research, Curriculum Center, 130 W. Fifty-fifth St., New York 19, N.Y., 1955.
9. *The Traveling Elementary School Science Library.* American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington 5, D.C., 1962. 47 pp.

SOURCES OF FILM AND FILMSTRIPS

Many companies produce excellent films and filmstrips for elementary science. Although some large school systems buy films and have their own film library, usually films are rented. Many museums and state universities have their own rental libraries, and will send catalogs upon request. The catalogs include a short summary of the contents of each film to help in

making the appropriate selection. A number of industrial firms also produce excellent films that can be rented at a very nominal cost. Filmstrips, which are much less expensive than films, are usually bought.

The following are some of the companies that produce or distribute films and filmstrips. They will all send catalogs upon request.

1. Academy Films, 800 N. Seward Street, Hollywood 38, Calif.
2. Almanac Films, Inc., 516 Fifth Ave., New York 36, N.Y.
3. Association Films, Inc., 347 Madison Ave., New York 17, N.Y.
4. Atlantis Productions, Inc., 7967 Sunset Blvd., Hollywood 46, Calif.
5. Audio Visual School Service, 114 E. Thirty-first St., New York 16, N.Y.
6. Bailey Films, Inc., 6509 DeLongpre Ave., Hollywood 28, Calif.
7. Cenco Educational Films, 1800 Foster Ave., Chicago 40, Ill.
8. Churchill-Wexler Film Productions, 801 N. Seward St., Los Angeles 38, Calif.
9. Coast Visual Education Co., 5620 Hollywood Blvd., Hollywood 28, Calif.
10. Coronet Instructional Films, 65 E. South Water St., Chicago 1, Ill.
11. Curriculum Materials Corp., 1319 Vine St., Philadelphia 7, Pa.
12. DeVry Corporation, 1111 Armitage Ave., Chicago, Ill.
13. Walt Disney Productions, Educational Film Dept., 477 Madison Ave., New York 22, N.Y.
14. Educational Horizons, 3015 Dolores St., Los Angeles 65, Calif.
15. Encyclopaedia Britannica Films, 1150 Wilmette Ave., Wilmette, Ill.
16. Eye Gate House, Inc., 146 Archer Ave., Jamaica 35, N.Y.
17. Film Associates of California, 10521 Santa Monica Blvd., Los Angeles 25, Calif.
18. Filmstrip House, 347 Madison Avenue, New York 17, N.Y.
19. Frith Films, 1816 N. Highland Ave., Hollywood 28, Calif.
20. Gateway Productions, Inc., 1859 Powell St., San Francisco 11, Calif.
21. The Jam Handy Organization, 2821 E. Grand Blvd., Detroit 11, Mich.
22. Moody Institute of Science, 11428 Santa Monica Blvd., Los Angeles 25, Calif.
23. National Audubon Society, Photo and Film Department, 1130 Fifth Ave., New York 28, N.Y.
24. Park Films, 228 N. Almont Drive, Beverly Hills, Calif.
25. Rampart Productions, 401 Taft Bldg., Los Angeles, Calif.
26. Resources for Education, Inc., 63 Fourth Ave., Mount Vernon 4, N.Y.
27. Society for Visual Education, Inc., 1345 W. Diversey Pkwy., Chicago 14, Ill.
28. Tabletopper Productions, 111 E. Sixth Street, P.O. Box 706, Carson City, Nev.

29. United World Films, Inc., 1445 Park Ave., New York 29, N.Y.
30. Roy Wilcox Productions, Inc., Allen Hill, Meriden, Conn.
31. H. W. Wilson Co., 950 University Ave., New York, N.Y.
32. Young America Films, McGraw-Hill Book Co., Text-Film Dept., 330 W. Forty-second St., New York 36, N.Y.

CHAPTER

8

Evaluation *of* Science Learning

EVALUATION is the *how well* of science teaching and learning. Earlier chapters discuss the *why, what,* and *how* of science teaching. These factors are the three components considered essential for the effective teaching and learning of science in the elementary school. The term *why* refers to the objectives of elementary science, the term *what* to the science content, and the term *how* to the methods of teaching science.

Evaluation, then, refers to how well the teacher has achieved the objectives of the elementary science program, how well the children have learned the basic science information and developed desirable behaviors, and how well the teacher has used appropriate learning techniques in the classroom. It should be quite obvious, therefore, that evaluation is vital to teaching and learning and must be an integral part of the science program in the elementary school, if the program is to be effective.

Prerequisites for Effective Evaluation

ALTHOUGH there are several excellent textbooks on evaluation and testing techniques available to the elementary school teacher, the role of evaluation in elementary science should be discussed briefly now. Science is still comparatively new in the elementary school. The transition from incidental and unstructured science programs to planned programs with definite scope and sequence is taking place slowly. There is general agreement about the objectives of elementary science, and a trend toward consistency in content, methods, and grade placement is being established. Common elements in scope and sequence appear more frequently in the newer elementary science programs and in textbooks.

When science in the elementary school was in a state of flux, it was easy to understand why little attention was paid to evaluation. Usually, evaluation was directed toward appraising the learning of factual information. Even the scattered, standardized commercial tests available in elementary science were forced to limit themselves to this kind of evaluation. Now that science in the elementary school has more definite form, however, there is an obvious need for improved evaluation and the wide variety of purposes for which it can be used.

If evaluation of science in the elementary school is to be effective and successful, a number of prerequisites must be met.

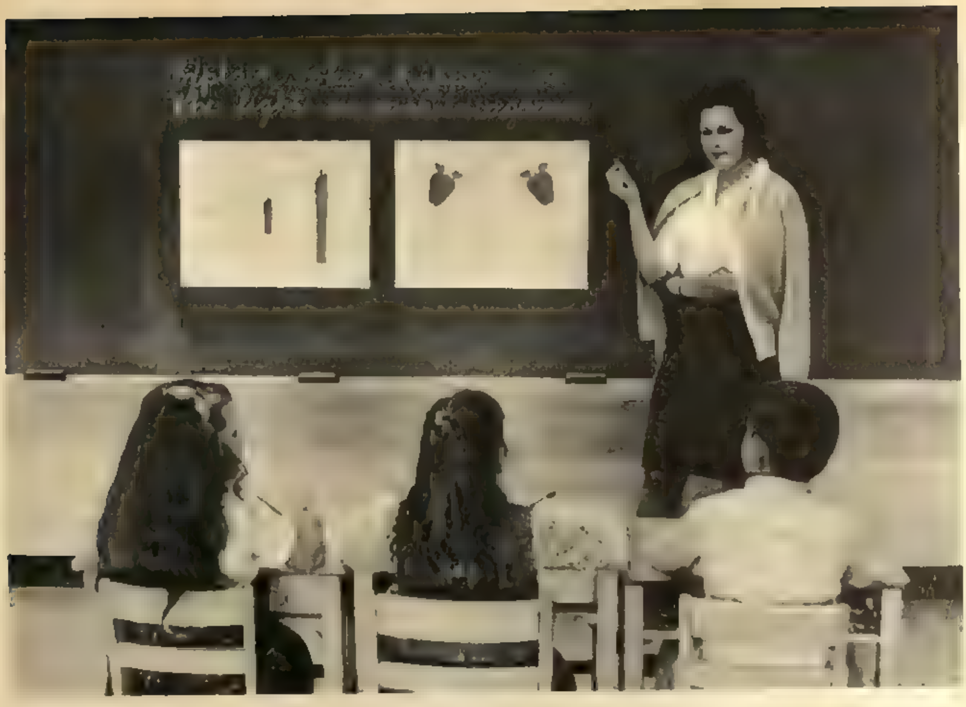
APPRAISAL OF ALL THE OBJECTIVES

Evaluation requires more than testing for simple recall or factual knowledge. Evaluation should attempt to appraise all the objectives of elementary science. These objectives include both the learning of basic science information and the development of desirable behaviors. Consequently, it is imperative that the elementary school teacher become thoroughly familiar with the objectives of elementary science.

To evaluate effectively the children's growth in knowledge and understanding of basic science information, the teacher must know the major science concepts, together with the facts, laws, principles, understandings, and generalizations that make up these concepts. To evaluate effectively the development of desirable behaviors, the teacher must first know exactly what behaviors are entailed in solving problems, in thinking critically, and in developing abilities and skills, scientific attitudes, appreciations, and interests. These behaviors must then be stated simply and clearly, in specific behavioral terms, so that they can be easily tested or observed.

CONTINUOUS EVALUATION

Usually, teachers tend to do most of their evaluation toward the end of a unit. However, good teaching and learning call for continuous evaluation by both the teacher and children. For the teacher it should be apparent that objectives, content, and methods in elementary science are interrelated and interdependent. As a result, the teacher should constantly evaluate



Evaluation can be used to appraise achievement.

the objectives of the science program, the content being learned, and the methods and materials being used to see if the children are achieving the objectives of the program. The teacher should also constantly evaluate the evaluation techniques themselves. On the other hand, the children should constantly evaluate their growth in science learning and in behaviors, their strengths and their weaknesses, and their progress both with relation to their individual abilities and with the abilities of their classmates.

VARIETY OF PURPOSES

Most of the purposes for which evaluation may be used can be classified under three main categories. First, evaluation can be used to appraise achievement. Here the teacher tries to determine how well the children have learned the basic science information and developed desirable behaviors.

Second, evaluation can be used for diagnostic purposes. As such, evaluation can help identify children's strengths and weaknesses. The teacher can then redirect the learning activities and work toward correcting the weaknesses. Evaluation can determine how well the children can work individually and in groups. This evaluation can be carried on by both the teacher and children. Evaluation can also be used as a pretest to explore and plan for future instruction. Finally, the teacher can use evaluation to diagnose the effectiveness of the teaching methods being used. This technique enables the teacher not only to learn whether other methods should be used when planning future learning activities, but also to learn which methods are most effective for a particular group of children.

Third, evaluation can be used for predictive purposes. In this case the

teacher tries to predict the children's behavior and achievement in the future or under different conditions. This kind of evaluation is becoming more important as a guide for placement in team teaching, tracks, or other forms of homogeneous grouping.

VALIDITY

During the school year the teacher will have ample opportunity to use a variety of techniques to evaluate progress in elementary science. When using these techniques the teacher should clearly know what each technique can and cannot do. No matter which technique the teacher selects and uses, the teacher should always be concerned about two characteristics that determine how effective the technique really is.

One characteristic is the validity of the technique. Validity is the degree with which a technique measures what it intends to measure. In other words, when the teacher uses an evaluative technique, is the technique really testing what the teacher wants to test? For example, if the teacher wants to find out if the children have learned how the position of the fulcrum in a first-class lever will make a difference in the amount of effort exerted, the teacher should carefully select a test question or situation that will clearly indicate that this is what the teacher is evaluating. One way this evaluation could be done would be to make a line drawing of a first-class lever, showing a weight at one end of the lever, an effort at the other end, and a fulcrum at a certain position between them. The children would then be asked to predict the effect of the fulcrum's position on the effort exerted.

RELIABILITY

Reliability is the second characteristic the teacher should consider when deciding how effective an evaluative technique is. Reliability is the accuracy and consistency with which a technique measures what it is measuring. In other words, when the teacher uses an evaluative technique, how well does the technique measure what the teacher wants to test? No technique can have real validity unless it also has reliability.

The need for reliability can be shown quite clearly with the example just described, that of the effect of the fulcrum's position on the effort exerted in a first-class lever. If the teacher asks the children to predict this effect on the basis of just one position of the fulcrum, the answer will give the teacher no real assurance that the children really know what will happen. It is necessary to use several positions of the fulcrum and have the children successfully predict what will happen in each case for the teacher to be confident that the children definitely know how the fulcrum's position affects the effort exerted. Thus, the greater the number of test questions or situations is, the higher the reliability will be. And the higher the reliability is, the more consistent the children's scores will be.

USE OF APPROPRIATE TECHNIQUES

In science, as in other areas of the elementary school curriculum, there is no one evaluative device that can be used exclusively for appraising the

teaching and learning process. All kinds of techniques are necessary to measure the children's progress in learning basic science information, their growth in solving problems and thinking critically, and their development of desirable behaviors. Even though some of our existing techniques may need refining, the teacher is still more likely to obtain a fairly adequate and complete picture of each child by using a variety of devices rather than by relying upon just one form or instrument.

There are many different methods of evaluation available to the elementary school teacher. These methods may be classified under three broad groups, namely, oral methods, written methods, and observation methods. Within each group there are a variety of instruments that can be used. Teachers vary in their preference of instruments. However, regardless of which instrument is preferred, there are certain points the teacher should keep in mind when selecting or constructing an evaluative device.

First, the teacher should remember that the objectives to be evaluated are more important than the kind of instrument to be used. Actually, the desired objectives or outcomes will play an important part in the kind of instrument selected. For example, evaluation of the ability to manipulate apparatus might require an appropriate experiment or demonstration, accompanied by observation. A problem situation could be used to test the ability to reason and interpret, form hypotheses, and draw conclusions. Evaluation of recall or identification might require an objective test.

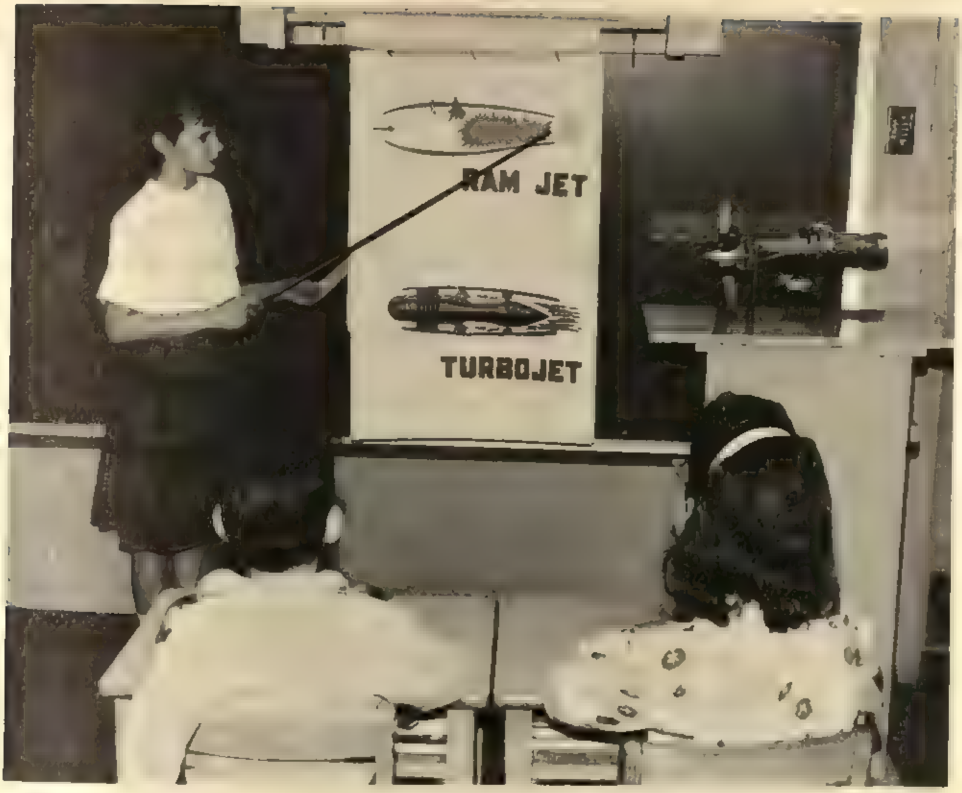
Second, good test questions are difficult and time-consuming to prepare, and they should be constructed with much thought and care. Finally, all tests contain an element of subjectivity, some tests more than others. The subjectivity can be largely restricted by checking the findings from one technique with those findings obtained from other techniques.

Oral Methods of Evaluation

Although objective tests are quite popular in the elementary school, there is still a great reliance upon oral methods of evaluation. Such methods are especially necessary in the lower elementary grades. The most commonly used oral techniques seem to be question and answer, discussion, and oral reports.

The question-and-answer method, perhaps more commonly known as oral recitation, is most widely used, although it has serious drawbacks as an evaluative technique. It can reach only a limited number of children, and therefore it is quite likely to have a low reliability. Not only is it unreliable because of inadequate sampling, but also because the questions will usually vary in difficulty. Moreover, there is a tendency for teachers to test recall or memorization of facts when using this technique.

Discussion is much more effective. It can involve a larger number of children at one time. When properly conducted, discussion can be useful in appraising the children's knowledge of basic science information, in determining scientific attitudes and other behaviors, and in diagnosing the



Using oral methods of evaluation.

children's strengths and weaknesses. Some teachers combine question and answer skillfully with discussion to obtain a highly effective evaluative instrument.

Oral reports can be another useful means of evaluation. Suggestions for using this technique successfully in the classroom have been described in detail in Chapter 4, "Methods of Teaching Science."

Written Methods of Evaluation

Written methods of evaluation have a definite place and function in the elementary science program. These methods include the use of essay tests, objective tests, and written reports. Usually, there is a tendency for elementary teachers to ignore the use of essay tests or questions, confining themselves primarily to simple objective tests, especially true-false tests, and written reports. This failure to use essay questions is a mistake because essay questions have unique functions, lending themselves well to effective evaluation.

Because essay questions involve more abstract thinking and because the technique of written expression is still comparatively new for the children, it may be wise to use essay questions mostly in the upper elementary grades.

The best arrangement seems to be a combination of objective and essay questions, with approximately one essay question offered per test.

Discussion of written methods of evaluation in this chapter will be limited only to essay and objective tests. Written reports have already been discussed in Chapter 4, "Methods of Teaching Science."

ESSAY QUESTIONS

Essay questions have distinct advantages. They can be constructed quickly. They can be used to measure how well children can analyze problems, think critically, recall and select previous knowledge, organize and present thoughts or ideas, arrive at conclusions, and show creativity and originality. They can also be quite helpful to the teacher in diagnosing partially understood science concepts or incorrect interpretations.

Essay questions have definite disadvantages as well. They do not allow for adequate sampling because only a few questions can be asked at one time. As a result they tend to have low validity and reliability. They take much time to correct. They are often worded so that they are vague and ambiguous. They can be scored in a highly subjective manner. The teacher often will either have a rudimentary scoring key or no key at all. As a result the children's marks on essay questions may be affected by such extraneous factors as neatness, grammar, spelling, or the children's previous performances (halo effect).

With a little care, some of these disadvantages can be eliminated, especially vagueness, ambiguity, and unreliable scoring. In such cases the chief difficulty seems to be the way in which the essay question is constructed. So many teachers do not spend enough time or effort to word the questions carefully and completely. Instead they tend to ask broad, almost meaningless, "discussion" questions. Typical examples are as follows:

1. Discuss tides and their effects.
2. Discuss friction and how it affects us.

Such questions can be very difficult for children to answer. They give the children no direction so that the children do not have a clear idea of what the teacher wants or expects of them. At the elementary school level the children are not particularly adept at organizing and presenting their thoughts or understandings. When left to their own devices, the children are likely to turn in a wide variety of responses. Some answers may be short and incomplete. Other answers may be quite detailed, rambling, and lengthy, perhaps with much extraneous material. These kinds of answers are hard to score because they are so highly disorganized.

The difficulty may be greatly alleviated if the teacher takes time to give the children some direction. One method, which has proved to be quite helpful, is for the teacher to divide the essay question into a number of parts. Each part is worded clearly and carefully, asking for specific information pertaining to the major concepts called for in the essay question. The difference in approach is immediately obvious when the same two essay questions listed above are now written as follows:

1. Every day the waters of the ocean rise and fall to give us high tides and low tides.
   a. What causes these high tides and low tides?
   b. Why do we get two high and two low tides a day?
   c. Why are some high tides higher than others at certain times?
2. Friction is a common occurrence in our daily life.
   a. What causes friction?
   b. How can friction be increased?
   c. How can we reduce friction?
   d. What are some of the useful effects of friction?
   e. What are some of the harmful effects of friction?

Notice how much easier it will now be for the children to attack these questions. They know exactly what the teacher wants of them, yet the teacher has given them no clues or answers, only directions. Furthermore, the parts of the essay question are presented so that the children's answers will provide a logically organized sequence of concepts. This method may set up a habit pattern that will be helpful to the teacher when showing the children how to organize their thinking and writing. Finally, this improved type of essay question is much easier to score. The teacher can examine each part of the question, determining how many key ideas are involved and what they are worth. From this examination the teacher can arrive at a much more objective scoring key, thus reducing subjectivity.

PROBLEM-SITUATION QUESTIONS

The essay questions described above usually call for explanation, description, or identification. Problem-situation questions are also essay questions, but are more concerned with attempting to measure the behaviors involved in solving problems and thinking critically. Such questions have already become popular in the high school and junior high school, and are now beginning to be found in the elementary school.

Perhaps the simplest form of the problem-situation question is more commonly known by many teachers as a "thought" question. Here the children are asked either to explain familiar and new phenomena around them, or to make predictions on the basis of changed conditions. This procedure is excellent for finding out if the children have really learned science principles rather than just memorized them. At the same time the children are required to think critically by observing closely the elements involved in the phenomenon, recognizing the science area to which it belongs, mentally reviewing concepts that seem to be pertinent, and then selecting the concept that explains the phenomenon satisfactorily.

The following are examples of such thought questions:

1. During the summer why does a swimmer feel cooler when coming out of the water on a windy day than on a calm day, even though the temperature is the same during both days?

2. In the summer why do we get a breeze that blows in from the land in the morning and from the ocean in the afternoon?
3. When your mother cannot unscrew the metal cover from a bottle, even after tapping it, why will pouring hot water over the cover often succeed in loosening it?
4. What would happen to conditions on earth if the earth did not turn on its axis?
5. What would happen to conditions on earth if the earth's axis were not tilted?

A more complicated form of problem-situation question describes a situation in varying detail. Several reasons, all apparently logical, are offered to explain the situation. The children are asked to consider the reasons carefully, select the correct one, and explain why each of the other reasons could not be correct.

The following has often been used as an example of this kind of question:

> One evening, during a thunderstorm, a boy walks into his room and sees that his table lamp has fallen over. He sets the lamp upright again and flips the switch to see if the lamp is all right. Just then there is a violent flash of lightning. The lamp does not light up, but now the overhead light in his room goes out. The boy flips the lamp switch back and forth. The switch clicks, but the lamp still does not light up. The boy looks out the window and notices that the lights are still on in his friend's house next door.
>
> Which one of the reasons given below is the most likely to explain why the table lamp did not light up? Explain why the other reasons could not be correct.
>
> 1. The filament inside the bulb was broken.
> 2. The light switch did not work.
> 3. There was a short circuit in the wires connected to the lamp.
> 4. The flash of lightning put out the lights in the neighborhood.

Questions of this type can be extremely effective evaluative devices. They help determine how well the children can classify and interpret the data properly, weigh the evidence, recall science concepts, formulate hypotheses, check both the interpretations and the hypotheses against the data, and arrive at conclusions that can be justified. However, very few, if any, ready-made questions of this type are available. They are difficult to prepare, and their construction taxes the ingenuity of the teacher. Yet their value can be so great that they are worth the time and effort expended.

OBJECTIVE TESTS

Objective tests are short-answer tests. There are four types of items generally associated with such tests, namely, true-false, completion, multiple-

choice, and matching items. An objective test may consist exclusively of items of one type only, or it may include items of two, three, or even all four kinds. These tests are used more commonly in elementary science than all other tests.

The advantages of using objective tests are numerous. They can be designed to evaluate specific outcomes, and still be scored very objectively. Also, many questions can be asked in a relatively short testing time. As a result, the objective test tends to have high validity and reliability. Because of its objectivity, the test can be scored very quickly and easily. Extraneous factors, such as grammar and neatness, do not interfere with the scoring; and subjectivity—with its partiality or halo effect—is reduced. Finally, the objective test can be used for a wide variety of purposes.

On the other hand, objective tests have drawbacks. Unless they are carefully thought out and worded, the test items may be obvious, misleading, or ambiguous. An even more serious limitation is the strong tendency of teachers to construct the tests so that they are primarily directed toward the evaluation of isolated bits of knowledge and memorization or cheap recall, all of which constitute superficial learning. It may be hard work to prepare good objective test items, but, after they are prepared, they can be used over and over again.

A good objective test has several characteristics. Some of the more pertinent ones are as follows:

1. It should be constructed as carefully as possible, keeping in mind the objectives to be evaluated.
2. It should bring out the best thinking and efforts of the children, rather than encourage guessing or bluffing.
3. It should be as objective as possible.
4. It should have adequate sampling.
5. It should have a high validity and reliability.
6. It should contain items that are brief and easy to read, to avoid ambiguity and confusion.
7. It should contain carefully worded items, to avoid questions that mislead, are obvious, give cues to answers for other questions, or provide clues because of transparent grammar, word form, or phrasing.
8. It should include items of varying difficulty so that the teacher can measure individual learning differences in the children.
9. It should give directions that are simple, clear, and complete.
10. It should be easy and quick to score.

TRUE-FALSE ITEMS

With items of this type the children indicate by a T and F (or + and o) whether the sentence is true or false. Examples of true-false items are as follows:

DIRECTIONS: The following sentences are either true or false. If a sentence is true, put a T on the blank line. If a sentence is false, put an F on the line instead.

_____ 1. A cirrus cloud looks like a large puff ball of cotton.
_____ 2. A dry cell changes chemical energy into electrical energy.

True-false items are the most widely used objective test items. They are extremely popular because they are easy to construct and very objective, many can be put on a single page, and the scoring is very quick and easy. However, the true-false test is the objective test most criticized because of its decided drawbacks. Most true-false items call for rote memory or cheap recall, rather than broad understandings. They encourage guessing. The questions are often obvious, vague, or tricky. Sometimes the items are worded so that they supply clues. Sentences containing such words as "all," "none," "always," or "never" are usually false. Those sentences that contain "some," "generally," "may," or "should' are usually true.

The quality of true-false items can be improved if the teacher devotes much care in preparing the test sentences, trying to relate them as much as possible to significant science concepts rather than to unrelated facts. Also, guessing may be discouraged by modifying the directions so that, if the sentence is false, the children must replace an underlined word with another word that will make the sentence true. The following shows how the two true-false items described above can be modified in this manner:

DIRECTIONS: The following sentences are either true or false. If a sentence is true, put a T on the blank. If a sentence is false, on the blank line put another word that will take the place of the underlined word in the sentence and will now make the sentence true.

_____ 1. A <u>cirrus</u> cloud looks like a large puff of cotton.
_____ 2. A dry cell changes <u>chemical</u> energy into electrical energy.

COMPLETION ITEMS

In this type of item the children are required to fill in a blank line, which will complete the sentence. The following are examples of completion items:

DIRECTIONS: Complete each sentence by writing the word or words that make the sentence correct.

1. The layer of atmosphere closest to the earth is called the _____________.
2. When the moon passes between the sun and earth, the kind of eclipse we get is called _____________.
3. The point around which a lever turns is called a _____________.

Completion items are also very widely used and quite popular. They are easy to construct and can be highly objective. They are also easy and quick to score. Unfortunately, most of these items also call for memorization and recall. When constructing completion items, the teacher should avoid making indefinite and ambiguous statements. Moreover, the blank line in the sentence should call for only one word or at most a very short phrase. Otherwise the item will be very difficult to score, especially if the answer is partially correct. Most teachers find these items easier to score if the omitted word or phrase is placed at the end of the sentence.

MULTIPLE-CHOICE (SELECT-THE-BEST-ANSWER) ITEMS

These items usually consist of either an incomplete sentence followed by several possible completions or a direct question followed by several possible answers. As a rule, four possible completions or answers are offered, all equally plausible and appropriate, and the children are required to select the one that is most appropriate. Examples of multiple-choice items are as follows:

DIRECTIONS: Choose the word or words that will best complete the sentence. Put the letter of the best answer on the blank line beside the sentence.

_____ 1. A flame is a mass of burning

(a) heat; (b) gas; (c) liquid; (d) solid.

_____ 2. If all four strings were equally tight, the one that would make the lowest-pitched sound would be

(a) short and thick; (c) long and thick;
(b) short and thin; (d) long and thin.

Multiple-choice items are generally considered the best type of objective test items. Although they are more difficult to prepare, they can be much more valid and reliable than true-false or completion items. When properly designed, the items can evaluate understanding of major concepts, reasoning and judgment, the ability to see relationships, and the ability to apply science principles to explain familiar or new phenomena. Multiple-choice tests are well liked by the children, can be very objective, and are easy and quick to score.

Some forms of problem-situation questions are really multiple-choice items, with the additional requirement that the children justify their selection of the correct answer.

MATCHING ITEMS

A matching item is essentially a group of multiple-choice items arranged in two columns; the children are asked to associate the items. The following is an example of a matching item.

DIRECTIONS: In the blank space next to each word in the first column put the letter of the best answer from the second column.

______ 1. nutcracker	a. first-class lever
______ 2. block and tackle	b. inclined plane
______ 3. knife	c. second-class lever
______ 4. door handle	d. screw
______ 5. ramp	e. pulley
______ 6. tweezers	f. wedge
	g. wheel and axle
	h. third-class lever

Matching items are well suited for determining if the children can associate science principles with examples of the principles, materials with their uses or function, and persons with discoveries or events. These items are very compact so that many can be put on one page. However, they often tend to test primarily memory or recall, and they are tedious and time-consuming to prepare.

It is usually wise to have more items in one column than in the other, for two reasons. First, if there are five items in each column and a child matches the first four correctly, the child gets the fifth answer without having to work. Second, if both columns have the same number of items and a child matches one pair of items incorrectly, the child must automatically get a second pair incorrect.

A variation of the matching item is to have a diagram or picture with numbered or lettered parts. The children are asked to identify each part and/or describe its function. Although this kind of item is aimed primarily toward recall, it does serve to inform both the teacher and children how much the children know and have yet to learn.

Methods for Observation of Behavior

OBSERVATION of behavior is a valuable method of evaluation because it supplies evidence that cannot usually be obtained by the other evaluative methods, and thus it helps give the teacher a more complete appraisal of the child. As a result, it plays a vital role in the evaluation of the children's growth, in determining the effectiveness of the teaching-learning process, and in ensuring the successful administration of the entire science program.

It is often ignored by teachers who either are not aware of its potentialities or are reluctant to accept it as a valid evaluative device. Teachers are constantly observing children and drawing conclusions about the children's growth and changes in behavior. Yet many of the same teachers, by being concerned about the apparently high degree of subjectivity of these observations, are inclined to think that the observations lack both validity and reliability. Consequently, the belief has become widespread that observation of behavior is an unreliable method of evaluation.

The element of subjectivity, when making observations can be greatly

Observing desirable behaviors.

reduced, or even eliminated, if the teacher will take certain precautions. First, the teacher should be thoroughly familiar with the behaviors described in Chapter 2, "Objectives of Elementary Science." These behaviors must be expressed in specific terms so that they can be easily observed and identified. This procedure will enable the teacher to gather evidence that is objective and concrete. Second, the teacher should give every child an equal number of opportunities to show whether growth in desirable behaviors has taken place.

Third, if the teacher is aware of the subjectivity in this kind of evaluation and conscientiously tries to avoid it, there will be less possibility of bias in the observations. Fourth, the teacher should keep in mind that quality of behavior will vary greatly among children at different grade levels in the elementary school. Standards must be different, then, for children of different age groups. For example, first-graders cannot manipulate materials or follow instructions as well as third-graders, and the third-graders will not perform as well as sixth-graders. Consequently, the teacher should not look for perfection as much as for steady growth.

There are several techniques available for observing and recording behaviors. Some of the more common techniques include descriptive records, checklists, and rating scales. Regardless of which technique is used, in all

cases the teacher should keep a permanent record of each child's growth in behavior. These records should be consulted periodically to give the teacher some indication of how well the children are doing and what can be done to help them. At appropriate intervals the teacher should have a conference with each child to make him aware of his progress and his strengths and weaknesses.

ANECDOTAL RECORDS

In this technique the teacher records a short statement or two, describing a particular remark or action by a child that showed evidence of changed behavior. The statement should be recorded as soon as possible after the observation was made. In time the teacher will have accumulated enough material about each child to furnish pertinent and significant information about the child's growth in desirable behaviors.

RECORDING REMARKS VERBATIM

This technique is better than the technique of using anecdotal records because it tells precisely what the children said. But there is one drawback. It is difficult for the teacher to write down remarks verbatim while discussion is going on, and it is time-consuming as well. This problem can be somewhat alleviated by either using tape recordings at periodic intervals or by remembering the most pertinent remarks and adding them verbatim to the anecdotes as soon as possible.

CHECKLISTS AND RATING SCALES

These techniques are essentially similar, and they are quite popular with teachers. They can be used to evaluate both individual and group behavior when children are conducting experiments, giving reports, solving problems, and participating in discussion or other classroom activities. The results can be used to evaluate each child's progress over a period of time, and also to compare the progress of one child with that of the rest of the class.

For each activity the teacher makes a list of desirable behaviors involved in the activity. In a checklist the teacher then checks off whether or not the behaviors were manifested by the children. Some teachers prefer to assign a code number or letter to each behavior. As each child demonstrates evidence of one of the behaviors, the teacher enters the appropriate number on a sheet containing a list of all the children's names. This procedure enables the teacher to gather evidence quickly and as often as is considered feasible. In time the teacher will have a sizable cumulative record of changes in behavior.

Rating scales are like checklists, except that they introduce the factor of quality. The same behaviors can be rated on a scale ranging from excellent to poor. The teacher thus has the added advantage of being able to evaluate the degree with which the children are developing desirable behaviors. Rating scales, like checklists, can also be used to evaluate individual and group behavior.

PART TWO

Basic Science Information, Learning Activities, AND *Bibliography for Science* IN THE *Elementary School*

THE EARTH AND THE UNIVERSE

CHAPTER

9 The Universe

THE SUN

I. The Nature of the Sun

A. The sun is a star.
   1. It is only one of the billions of stars that make up the universe.
   2. It is not a large star, but it looks larger than the other stars because it is so much closer to us on earth.

B. The sun is much larger than the earth.
   1. The diameter of the sun at its equator is about 863,000 miles, which is about 109 times larger than the diameter of the earth.
   2. If the sun were a hollow ball, we could place more than a million earths into it.

C. The sun is about 93,000,000 miles from the earth.

II. The Sun Gives Off Energy

A. Like all other stars, the sun gives off a vast amount of radiant energy, including light.

B. This energy does not come from ordinary burning.

C. The energy comes from a nuclear reaction that takes place inside the sun.
   1. Astronomers believe that hydrogen atoms in the sun keep combining to form helium atoms.
   2. While the helium is being formed, some of the hydrogen is converted into tremendous amounts of energy.

D. The energy from a hydrogen bomb is produced the same way except that the reaction in a hydrogen bomb lasts for a moment, and the reaction in the sun goes on all the time.

E. Because of this nuclear reaction, the sun is a very hot body.
   1. The temperature at the surface of the sun is about 10,000 degrees Fahrenheit.
   2. At the center the temperature may be as high as 36,000,000 degrees Fahrenheit.

III. The Parts of the Sun

A. The sun is not a solid body like the earth, but it is a huge ball of very hot gases.

B. Three layers of gases, which are often called the sun's atmosphere, surround the main body of the sun.

C. The first layer is called the **photosphere**.
   1. The photosphere glows brilliantly and is the source of most of the sun's light.
   2. The photosphere goes up 100 to 200 miles.

D. Beyond the photosphere is a second layer of gas called the **chromosphere**.
   1. This layer of gas is bright red, and it can only be seen when the sun is blotted out in a total eclipse.

2. The chromosphere rises about 8000 miles above the photosphere.

E. A silvery halo of gases, called the **corona,** surrounds the chromosphere.

1. The corona also can only be seen when there is a total eclipse of the sun.
2. The corona reaches out as far as a million miles in all directions.
3. The corona is very thin and glows with a weak light.

IV. Solar Storms

A. The sun seems to have violent storms on its surface.

B. These storms are tied up with the presence of **sunspots** on the sun's surface.

C. Sunspots are dark spots that seem to move slowly from east to west across the sun's surface.

1. Actually, the sunspots stand still while the sun turns on its axis.
2. The spots look dark because they are a little cooler than the surrounding, glowing gases.
3. The spots usually appear in the photosphere near the sun's equator.
4. Their size can range from 500 miles to more than 50,000 miles in diameter.
5. They often form in pairs, and sometimes they form in large groups.

D. Astronomers think that sunspots are caused by magnetic storms that take place within the sun.

E. These magnetic storms often affect the earth.

1. The storms send out electrified particles from the sun's surface.
2. When these electrified particles strike the earth's ionosphere, they interfere with radio, television, and long-distance telephone communication.
3. These particles also strike the earth's lower atmosphere and produce the brilliant show of colored lights near the north and south poles.
4. These colored lights are called the **northern lights** (Aurora Borealis) and the **southern lights** (Aurora Australis).

F. Sunspots usually appear in 11-year cycles, in which the sunspots reach their greatest number every 11 years.

G. Very often a **solar flare** accompanies a sunspot.

1. The solar flare is a bright cloud of gas that leaps up from the sun's surface.
2. The flare may cover an area of a billion square miles and shoot up as high as 300,000 miles.
3. The flare becomes 20 to 30 times brighter than the other areas of the sun, and then it fades away in about an hour.

H. When the sun's rotation carries a sunspot to the edge of the sun, **solar prominences** are sometimes formed.

1. These prominences send great streamers of bright gas thousands of miles into the sun's atmosphere.
2. These prominences are not as violent as flares, but they move more gracefully.
3. Some prominences suddenly rush back to the sun, whereas, others seem to be blown off the sun.

I. Although it seems fairly obvious that a big disturbance is going on inside the sun, scientists do not yet know the exact reason for the appearance of sunspots, followed by solar flares and prominences.

V. The Future of the Sun

A. Astronomers think that the sun has been producing energy for about five billion years.

B. They also think that the sun will continue to produce energy for many billions of years more.

C. When about 15 percent of its hydrogen atoms have been used up, the nuclear reaction inside the sun will speed up, slowly at first, then faster and faster.

D. The inside of the sun will get hotter, and the sun will expand to about 100 times its size.

E. Meanwhile the surface of the sun will become cooler, and its color will change to orange and then red.

F. When enough of the hydrogen has been used up, the sun will suddenly collapse and become so small that both its size and its light will be only a small amount of what they originally were.

G. The sun will become cooler and cooler, and fainter and fainter, until it finally becomes completely dark and cannot be seen at all.

THE SOLAR SYSTEM

I. The Members of the Solar System

A. The solar system is made up of a group of heavenly bodies that move around the sun.

1. These heavenly bodies are called **satellites.**
2. A satellite is any heavenly body that travels around another heavenly body.

B. The principal members of the solar system are nine large bodies called **planets.**

1. The word *planet* means "wanderer."
2. The planets were given this name because they seemed to wander over the sky instead of appearing to stay in a fixed position like the stars.
3. The names of the planets, in order of their increasing distance from the sun, are—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.
4. Between Mars and Jupiter there is a belt of several thousand bodies of different sizes, called **asteroids** or **planetoids,** which also move around the sun.

C. Planets are not stars.

1. Stars shine because they give off light, but planets shine because they reflect the light of the sun or other stars.
2. Planets are much smaller than the sun and most of the other stars.

D. The planets travel in an elliptical path, called an **orbit,** around the sun.

1. All the planets move or revolve in a counterclockwise direction (from west to east) around the sun.
2. The time needed for a planet to make one complete turn, or revolution, around the sun is called the planet's year.

E. The planets spin like a top, or rotate, as they travel around the sun.

1. They rotate around an imaginary line, called an **axis,** which runs through the north and south poles of the planet.
2. The time needed for a planet to make one complete rotation on its axis is called the planet's **day.**

F. Many of the planets have their own smaller satellites that revolve around them.

1. The satellites of the planets are called **moons.**
2. Astronomers have discovered 31 moons: one for Earth, two for Mars, twelve for Jupiter, nine for Saturn, five for Uranus, and two for Neptune.

G. The planets are all alike in certain ways.

1. They are all satellites of the sun.
2. They all revolve in a counterclockwise direction (from west to east).
3. They all rotate on their axis.
4. They all obtain their energy from the sun.
5. They all contain the same basic chemicals, although the proportions are different.

H. The planets are also different in many ways.

1. They differ in their distance from the sun.
2. They differ in size and heaviness.
3. They differ in the kind and amount of atmosphere they have.

4. They differ in the time it takes them to revolve around the sun.
5. They differ in the time it takes them to rotate once on their axis.
6. They differ in the number of moons they have.

I. In the solar system there are also bodies, called **comets,** which have long oval-shaped orbits that bring the comets very close to the sun and then far out into the solar system.

J. In the solar system there are also billions of fast-moving rocks of all sizes, called **meteors.**

II. How the Solar System Was Formed

A. Many theories have been proposed to explain how the solar system was formed.

B. All these theories fall into two general classes.
1. One class claims the solar system was formed quickly and violently.
2. Another class claims the solar system was formed slowly and moderately.

C. The older **planetismal theory** proposes that long ago the sun and another star collided.
1. Large amounts of matter were thrown out of the sun.
2. This hot material then cooled to form the planets.

D. The newer **planetismal theory** proposes that the two stars did not collide, but only came very close to one another.
1. The pull of gravity of one star upon the other raised great tides on the sun.
2. The materials that were lifted from the sun remained as large spiral arms.
3. As these spiral arms cooled, they broke away from the sun, shrank, and became the planets.

E. All the different versions of the planetismal theory have one serious weakness.
1. Astronomers believe that the material taken or raised from the sun or any other star would be millions of degrees hot.
2. This hot material would quickly spread out into space as a gas before it could cool to form the planets.

F. The **exploding star theory** proposes that long ago the sun had a companion star beside it.
1. The companion star exploded and most of the material was thrown into space.
2. However, a cloud of gas was left behind, held by the sun's pull of gravity.
3. From this cloud the planets were formed.

G. The **nebular theory** proposes that the sun and planets were formed from a large, whirling cloud of hot gas and dust.
1. As the cloud cooled and grew smaller, it began to spin faster, causing rings of matter to break away from the outer edge of the cloud.
2. The main part of the cloud eventually became our sun, and the rings became the planets.

H. The major weakness of the nebular theory is that mathematicians do not believe it is possible for rings of material to collect into balls of matter large enough to form the planets.

I. The **dust cloud theory** is the theory that seems to be most in agreement with the facts, and is the most widely accepted theory today.
1. According to this theory the solar system was formed from huge clouds of gases and dust.
2. The atoms in these gases and dust were pushed toward one another by the light from the stars, and they formed larger particles.
3. These larger particles were attracted to each other by the pull of gravity on one another, and they began to crowd together.
4. Large numbers of these particles came together, shrank, and grew heavier.
5. Eventually a huge ball of material was formed, with its particles all packed closely together.
6. The hydrogen atoms in the center of the ball began to collide with each other,

and gradually a nuclear reaction took place, with the formation of helium and the release of radiant energy, including light.

7. In this way the star, our sun, was formed.
8. Part of the cloud of dust and gases, from which the sun was formed, stayed all around this new star and slowly rotated.
9. Later, huge whirlpools formed in this rotating cloud, causing smaller globes of gases and dust.
10. Each globe eventually cooled into a planet that still revolves around the sun because of the original motion of the rotating cloud of gases and dust.
11. The satellites of the planets were formed the same way from this rotating cloud.

J. The dust cloud theory is very popular because it explains satisfactorily not only the formation of the sun and the solar system, but also the formation of all the stars and their satellites.

III. Why the Planets Revolve Around the Sun

A. There are two forces, acting on each planet at the same time, that keep the planets revolving around the sun.

B. One force is due to the inertia of the moving planet.

1. According to Newton's first law of motion, a body that is at rest will stay at rest unless some force starts it moving, and a body that is moving will continue to move in the same direction and at the same speed unless some force makes it change direction or speed.
2. Because the planet is already moving, if only inertia were acting on it, the planet would continue straight into space and far away from the sun.

C. The second force is the pull of gravity of the sun on the planet.

1. According to Newton's law of gravitation, every body in the universe attracts or pulls on every other body.
2. The heavier a body, the greater is its pull on another body.
3. Because the sun is heavier than any of its planets, the sun's pull of gravity on any given planet is very much more powerful than the planet's pull of gravity on the sun.
4. If only gravity were acting on the sun and each planet, the more powerful pull of the sun's gravity would make the planet rush quickly to the sun and burn up.

D. However, both inertia and gravity act on each planet at the same time and in such a way that the planet travels neither straight into space nor toward the sun, but instead it travels around the sun.

IV. Mercury

A. Mercury is the planet nearest the sun, and it is about 36 million miles away from the sun.

B. It is also the smallest planet, with a diameter of about 3000 miles.

C. It can be seen near the horizon shortly after sunset or just before sunrise.

D. It is sometimes called an "evening" or "morning" star, even though it is really a planet.

E. It revolves around the sun once every 88 days, so its year is much shorter than Earth's year.

F. It rotates on its axis only once during this 88 days, so its day is just as long as its year.

G. This type of rotation also means that one side of Mercury always faces the sun.

1. Therefore, one side is always light, and the other side is always dark.
2. The side that always faces the sun is very hot (about 700 degrees Fahrenheit) and the side away from the sun is very cold (about 460 degrees below zero Fahrenheit).

H. Both sides of Mercury do not have any air or water.

V. Venus

A. Venus is the next closest planet to the sun, and it is about 67 million miles from the sun.
B. It is about as big as Earth, with a diameter of about 7600 miles.
C. It also can be seen near the horizon as an "evening" star just after sunset and as a "morning" star just before sunrise.
D. It revolves around the sun once every 225 days, so its year is shorter than Earth's year.
E. Venus is surrounded by thick clouds; consequently, astronomers have not been able to learn exactly how long it takes Venus to rotate once on its axis.
F. Scientists think that the clouds surrounding Venus are made up mostly of carbon dioxide gas.
G. Radio signals seem to show that the temperature of the surface of Venus is about 585 degrees Fahrenheit.
   1. This high temperature means that any water on Venus would have boiled away.
   2. Most likely the surface is mostly bare rock and desert.
H. Venus is the brightest body in the sky next to the sun and moon because its thick clouds reflect so much sunlight.

VI. Earth

A. Earth is the next planet after Venus, and it is about 93 million miles from the sun.
B. It has a diameter of about 7900 miles.
C. It revolves around the sun once every 365¼ days, and it rotates on its axis once every 24 hours.
   1. At its equator Earth rotates at a speed of about 1000 miles an hour.
   2. This speed becomes smaller and smaller as we move away from the equator toward the poles.
D. Earth has one moon.
E. Earth is the only planet where the temperature of its surface is usually between the boiling and freezing points of water, so most of the water on Earth is found in the liquid state.
F. It is probably the only planet where life, as we know it, exists.

VII. Mars

A. Mars is the next planet after Earth, and it is about 140 million miles away from the sun.
   1. Mars is the closest planet to Earth.
   2. Every 15 years the paths of Mars and Earth come closer and there are only about 30 million miles between them.
B. It is a small planet, with a diameter of about 4200 miles.
C. It revolves around the sun once every 687 days, so its year is almost twice the length of Earth's year.
D. It rotates on its axis once every 24½ hours, so its day is just about the same as Earth's day.
E. It has two small moons.
F. It has seasons just like Earth.
   1. Astronomers can see an ice cap at its poles that grows smaller in the summer and larger in the winter.
   2. The surface also changes color with the seasons, growing darker in the summer and lighter in the winter.
G. About three fourths of Mars' surface is covered with bright reddish or yellowish patches, which astronomers think are deserts.
H. Mars has an atmosphere, but its air is much thinner than that on Earth, so there must be very little oxygen and water vapor in its air.
I. The average temperature on Mars is about 30 to 40 degrees below zero Fahrenheit, as compared to an average of about 60 degrees above zero Fahrenheit on Earth.
   1. During the day the temperature at the equator of Mars may be as warm as 60 to 70 degrees Fahrenheit.
   2. At night, however, the temperature

drops to about 100 degrees below zero Fahrenheit.

VIII. The Asteroids or Planetoids

A. The asteroids or planetoids are a belt of perhaps as many as 25,000 bodies that circle the sun between Mars and the next planet Jupiter.
B. They are called *asteroids* because they look like stars, and they are also called *planetoids* because they are really "little planets."
C. All the asteroids revolve around the sun in the same direction as the larger planets.
D. The asteroids are irregular lumps of rock, perhaps mixed with metal, that differ in size and brightness.
 1. Only a very few are larger than 100 miles in diameter.
 2. A few hundred are between 10 and 100 miles in diameter.
 3. The rest are less than 10 miles in diameter, with some perhaps only as large as basketballs.
E. Scientists do not know how the asteroids were formed.
 1. Some think they are part of a planet that exploded.
 2. Others think that they are the parts of two planets that collided and exploded.
 3. Still others think that they are part of the solar system that never grew large enough to form an ordinary planet.

IX. Jupiter

A. Jupiter is the next planet after Mars, and it is about 485 million miles from the sun.
B. It is the largest of the planets, with a diameter of about 87,000 miles, which is about eleven times that of Earth.
C. It appears as a very large "star" in the sky.
D. It revolves around the sun once in about 12 years.
E. It rotates on its axis once in about 10 hours, so it has a very short day.
 1. Its speed of rotation is very fast, that is, about 25,000 miles an hour at its equator, or about twenty-five times faster than Earth's speed of rotation at the equator.
 2. This rapid rotation makes Jupiter flatten at its poles and bulge at its equator even more than Earth does.
F. It has 12 moons.
G. Through the telescope Jupiter does not show a solid surface, but it does show shifting belts of clouds.
 1. These belts run parallel with its equator.
 2. These clouds are spread out in colored bands, which keep changing their patterns and colors.
H. Scientists think that Jupiter has a solid core of rock and metal that is about 40,000 miles in diameter.
 1. This core is surrounded by a layer of compressed ice.
 2. Next are the thick layers of different gases, one on top of the other, which make up Jupiter's atmosphere.
I. Jupiter has a red spot on it that changes in brightness from time to time.
J. Scientists think that Jupiter may be surrounded by radiation belts much like the Van Allen radiation belts on Earth.

X. Saturn

A. Saturn is the next planet after Jupiter, and it is about 890 million miles from the sun.
B. It has a diameter of about 75,000 miles.
C. It revolves once around the sun in about 29½ years.
D. It rotates on its axis once in about 10 hours.
E. It has nine moons.
F. It differs from all the other planets in that it is surrounded by three broad but thin rings that revolve at different speeds around its equator.
 1. Most scientists think that the rings are made of pieces of rock like that of the asteroids.
 2. These rocks may be as small in diameter as grains of sand or as large in diameter as a few miles.

XI. Uranus

A. Uranus is the next planet after Saturn, and it is about 1800 million miles from the sun.
B. It has a diameter of about 31,000 miles.
C. It revolves once around the sun in about 84 years.
D. It rotates on its axis once in about 10 hours.
E. It has five moons.
F. Like Jupiter, Saturn seems to have a solid core, surrounded by an icy layer and a thick atmosphere of gases.
G. Uranus rotates in a different position from all the other planets.
  1. All the other planets rotate on an almost vertical axis, like a top that is spinning the regular way.
  2. Uranus rotates on an almost horizontal axis, like a top that is spinning on its side.

XII. Neptune

A. Neptune is the next planet after Uranus, and it is about 2800 million miles away.
B. It has a diameter of about 33,000 miles.
C. It revolves once around the sun in about 165 years.
D. It rotates on its axis once in about 16 hours.
E. It has two moons.
F. Scientists call Uranus and Neptune the twin planets.
  1. They both are about the same size.
  2. They both are made up of a solid core, surrounded by an icy layer and an atmosphere of the same kinds of gases.
G. Neptune can be seen only through a telescope.

XIII. Pluto

A. Pluto is the last, and most recently discovered, planet in the solar system.
B. It is about 3700 million miles from the sun.
C. Astronomers are not quite certain of its diameter, but they think it is about 3600 miles.
D. It revolves once around the sun in about 248 years.
E. Astronomers do not yet know how long it takes Pluto to rotate once on its axis or how many moons it has, if any.

XIV. Comets

A. Comets are bodies that revolve around the sun in long, oval-shaped orbits.
  1. Instead of the sun being approximately in the center of a comet's orbit, it is at one far end.
  2. At the same time the comet's orbit cuts across the paths of the planets' orbits.
B. The comet has a head and a tail.
C. The comet's head is made up of a loose mass of small rocks and dust, mixed with frozen gases.
D. The comet does not have a tail until it nears the sun.
  1. As the comet nears the sun, the heat of the sun melts the frozen gases in the comet's head and changes them into vapor.
  2. The comet's tail is actually this very thin stream of gases.
  3. The tail may be millions of miles long and so thin that stars can be seen through it.
E. The head and tail of the comet reflect the light of the sun.
F. The pressure of the light from the sun makes the tail point away from the sun when the comet both approaches and leaves the sun.
G. The comet gains speed as it nears the sun and the sun's pull of gravity on it becomes stronger, then it slows down again as it travels away from the sun and the sun's pull of gravity on it becomes weaker.
H. Comets have very little weight, and, if the earth should pass through any part of a comet, most likely we would hardly notice it.

I. Some comets return rather quickly, but others take much longer to return.
   1. Encke's comet returns every 3⅓ years.
   2. Halley's comet returns every 76 years.

J. Some comets never return because they either waste away as material is forced out of the head into the tail or they are destroyed as they come near a larger body.

K. Scientists do not know exactly how comets were formed.

XV. METEORS AND METEORITES

A. Meteors are rocks in the space through which the earth passes as it travels around the sun.
   1. These rocks may be tiny grains of sand or they may be very large.
   2. Some meteors are metallic and have iron and nickel in them.
   3. Other meteors are stony and have silicates in them.

B. Billions of meteors enter the earth's atmosphere each year, traveling at a speed of about 100,000 miles an hour.

C. About 55 miles above the earth the friction of the air rubbing against the meteors makes them white hot, and they begin to burn.
   1. The burning meteors make a bright streak of light as they travel through the air.
   2. These bright streaks are called "shooting stars."

D. Most meteors burn up before they reach the earth's surface.

E. Those meteors that strike the earth's surface before they burn up are called meteorites.

F. If meteorites are large enough, they can form a large crater when they strike the earth.
   1. Meteor Crater in Arizona and Chubb Crater in Canada were probably made by meteorites.
   2. One meteor, weighing more than 60 tons, has been found in Africa and is still in the original spot where it struck the earth.
   3. Another meteor, weighing about 35 tons, is in the American Museum of Natural History in New York City, and was found by Admiral Peary in Greenland in 1894.

G. The meteors that reach Earth seem to come from two different sources.
   1. Most of them are probably small bits of rocks, like those in the belt of asteroids between Mars and Jupiter, that are traveling through space.
   2. Some also seem to come from comets because swarms of meteors called meteor showers are seen every time the earth crosses the path of a comet.

THE EFFECTS OF THE SUN ON THE EARTH

I. THE SUN CAUSES THE YEAR ON EARTH

A. The earth travels in an elliptical path, called an orbit, around the sun.

B. It moves around, or revolves, in this orbit in a counterclockwise direction (from west to east).

C. The time needed for the earth to make one complete turn, or revolution, around the sun is called the earth's year.

D. The earth's year is 365¼ days.

II. THE SUN CAUSES DAY AND NIGHT ON EARTH

A. The earth also spins like a top, or rotates, as it travels around the sun.
   1. It spins around an imaginary line, called an axis, which runs through the earth's north and south poles.
   2. It rotates on its axis in a counterclock-

wise direction (from west to east).
   3. The time needed for the earth to make one complete turn on its axis is called the earth's day.
   4. The earth's day is 24 hours.
B. At the equator the earth rotates at a speed of about 1000 miles an hour.
   1. This speed becomes smaller and smaller as we move farther away from the equator toward the north and south poles.
   2. Halfway between the equator and the North pole the earth's speed of rotation is about 800 miles an hour.
C. The earth gets its light from the sun.
   1. Because the earth is shaped like a ball, only one half can be lighted at one time by the sun.
   2. When one half is lighted by the sun, the other half is in darkness.
   3. The half that is turned toward the sun has daylight, or daytime.
   4. The half that is turned away from the sun is in darkness, or has nighttime.
   5. Every 24 hours, as the earth rotates once on its axis, one part of the earth will have had one period of daytime and one period of nighttime.
D. Because the earth turns from west to east, the sun seems to move across the sky from east to west.
E. Therefore, the sun seems to rise in the east and set in the west.
F. The sun looks bigger when it is just rising or setting.
   1. When it is seen against buildings or other objects on the horizon, it looks bigger by comparison.
   2. When it is by itself high in the sky, it looks smaller.
G. Also, when the sun is rising or setting, it looks orange or reddish.
   1. This phenomenon happens because rays of red light can pass through the thicker part of the earth's atmosphere much more easily than rays of blue light.
   2. When the sun is low on the horizon, the light from the sun must travel a much greater distance through the thicker part of the earth's atmosphere than when the sun is overhead.
   3. The blue rays in sunlight cannot get through this greater distance of air, and they are reflected and scattered by the dust particles in the air.
   4. The reflection and scattering of the blue light by the dust particles is what makes the sky appear blue.
   5. However, the red rays in sunlight can still pass through.
   6. The sunlight now has less blue in it, so the sun looks orange or reddish.
   7. When the sun is high in the sky, all the rays of light can get through this shorter distance of air so the sun looks white.

III. The Sun Causes the Seasons on Earth

A. The earth's axis is tilted at an angle of 23½ degrees, and it is always pointed toward Polaris, the North Star.
B. Because of this tilt and because of the earth's revolution around the sun, the earth has different seasons of the year.
C. When the northern hemisphere is tilted toward the sun, the northern hemisphere has summer.
   1. Summer takes place between June 21 and September 22.
   2. In the summer the sun's rays are shining directly upon the northern hemisphere.
   3. The stronger, direct rays cover a smaller amount of the earth's surface, and the surface becomes quite hot.
   4. Because of the tilt of the earth's axis, the northern hemisphere also gets more daylight than darkness in the summer so the days are longer than the nights.
   5. More daylight means that the northern hemisphere gets the stronger, direct rays of the sun for a longer time, which also helps the northern hemisphere become warmer in the summer.
   6. When it is summer in the northern hemisphere, the north pole has daylight all 24 hours.
D. When the northern hemisphere is tilted

away from the sun, the northern hemisphere has winter.

1. Winter takes place between December 21 and March 20.
2. In the winter the sun's rays are shining at a slant upon the northern hemisphere.
3. The weaker, slanted rays now cover a large amount of the earth's surface, and the surface is not heated as much.
4. Because of the tilt of the earth's axis, the northern hemisphere gets more darkness than daylight in the winter so the nights are longer than the days.
5. Longer nights mean that the northern hemisphere gets the sun's rays for a shorter time, which also helps the northern hemisphere become much colder in the winter.
6. When it is winter in the northern hemisphere, the north pole is in darkness all 24 hours.

E. When it is summer in the northern hemisphere, the southern hemisphere is tilted away from the sun and the southern hemisphere has winter.

F. When it is winter in the northern hemisphere, the southern hemisphere is tilted toward the sun and the southern hemisphere has summer.

G. In the spring and fall, the earth is tilted neither toward nor away from the sun.

1. Neither hemisphere receives strong rays of sunlight, and it is not summer or winter in both hemispheres, but rather somewhere between.
2. At the same time, the days and nights are just as long.
3. In the northern hemisphere spring is from March 21 to June 20, and fall is from September 23 to December 20.

IV. The Sun Is a Source of Energy for the Earth

A. The sun sends out radiant energy in all directions.

B. Only a very small part of the sun's energy travels to the earth.

C. This small part heats the earth and gives it light.

D. The sun's energy also makes it possible for green plants to make food.

1. These plants make food by a process called **photosynthesis.**
2. In this process the leaves of the plant take carbon dioxide from the air and water from the soil and change these materials into carbohydrates and oxygen.
3. The energy of sunlight and the green coloring of the leaves, called **chlorophyll**, cause the chemical reaction of photosynthesis to take place.
4. Photosynthesis is important because animals eat plants, and human beings eat both animals and plants.
5. The food we eat gives us energy and makes us grow.

E. Without the energy of sunlight, the earth would be frozen and lifeless.

F. The sun's energy is stored in natural fuels such as wood, coal, oil, and gas.

1. Coal is the remains of fernlike plants that died, were buried under masses of soil and rock, and then subjected to tremendous heat and pressure.
2. Oil and gas are the remains of tiny animals and plants that died, were buried under layers of mud and sand, and then subjected to tremendous heat and pressure.
3. When natural fuels are burned, they give off energy in the form of heat and light—the same energy that originally came from the sun and was stored in the plants by photosynthesis.

V. The Sun Causes the Weather

A. The sun does not heat every part of the earth equally.

1. The parts of the earth near the equator are heated more than the parts of the earth away from the equator because the rays of light become more slanted farther away from the equator.
2. Because the sun's rays heat only one half

of the earth at one time, a regular heating and cooling cycle is produced each day.

3. The land on earth is heated and cooled more quickly than water.
4. Dark-colored bodies of land absorb more heat than light-colored bodies.

B. This unequal heating causes movements of great masses of air.

1. Some air masses are cold, and others are warm.
2. The cold air masses come from the polar regions, and the warm air masses come from the tropical regions.
3. The warmer, lighter air from the equator rises and moves toward the poles, and the colder, heavier air from the poles moves down toward the equator.
4. The colder, heavier air masses have greater pressure than the warmer, lighter air masses.

C. At the same time the heat of the sun causes some of the water on earth to evaporate into the air and become a gas called water vapor.

1. The warmer the air masses, the more it expands, and the more water vapor it can hold.
2. The colder the air mass, the more it will contract, and the less water vapor it can hold.

D. When warm air masses meet cold air masses, the warm air masses are cooled, and some of the water vapor comes out of the air, or condenses, in different forms, called **precipitation.**

E. The combination of moving air masses, differences in air pressure, and changing amounts of water vapor in the air—all caused by the sun—are responsible for the different kinds and changes in weather throughout the earth.

THE MOON

I. The Nature of the Moon

A. The moon is a very large ball of rocky material that revolves around the earth.

B. It is about 2160 miles in diameter.

1. Its size is about one fourth of the diameter of the earth.
2. In volume, the moon is about one fiftieth of the size of the earth.

C. It weighs about one eightieth as much as as the earth.

D. Its pull of gravity is about one sixth of that of the earth.

1. A broad jumper who could jump 25 feet on earth would jump 150 feet on the moon.
2. A high jumper who could jump 7 feet high on earth would jump 42 feet high on the moon.
3. The high jumper would not fall any harder from the 42-foot height because he would weigh only one sixth as much on the moon as he did on earth.

E. The moon has no atmosphere.

1. Without air there is no wind on the moon.
2. Without air sounds cannot travel, and thus no sounds can be heard on the moon.

F. The moon has no water or water vapor.

1. There can be no brooks, rivers, lakes, or oceans on the moon.
2. There can be no clouds or weather.

G. The temperature on the surface of the moon varies greatly, depending upon whether it is day or night.

1. During the day the temperature is very hot, and it may be as high as 250 degrees Fahrenheit.
2. At night the temperature is very cold, and it may be as low as 200 degrees below zero Fahrenheit, or even lower.

H. The surface of the moon is made up of smooth plains, jagged mountains, and craters.

I. There are about 30 plains on the side of the moon that we can see.
   1. These plains cover about half the surface of this side, and they are shaped like rough circles.
   2. The plains appear dark because they do not reflect as much sunlight as the mountains.
   3. Early astronomers thought the dark areas were seas and the light areas were continents.

J. The surface of the moon is covered with a layer of dust particles, and possibly small rocks, that have fallen from space.
   1. A man who walked on the moon would kick up a cloud of loose dust.
   2. The dust would fall back to the surface just as quickly as heavy pieces of stone or iron because there would be no air to slow down the falling dust.

K. There are many mountain ranges on the moon.
   1. Most of these ranges are concentrated in the moon's southern hemisphere.
   2. Some of the mountains are more than 25,000 feet high.
   3. Astronomers have measured the height of these mountains by the length of the shadows they throw on the moon's surface.
   4. The mountains are very jagged because there are no forces of wind and water to wear them down to smoother and gentler forms.

L. There are also many rounded depressions, called **craters**, spread throughout the plains of the moon's surface.
   1. More than 30,000 craters have been counted on photographs of the moon.
   2. The largest crater is about 146 miles in diameter, and the smallest craters are only a few hundred feet in diameter.
   3. In most craters the floor of the crater is much lower than the plains surrounding them.
   4. In some craters the floor of the crater is above the level of the surrounding plain.
   5. Some craters have smooth floors, but others have very rough floors, often with smaller craters in them.
   6. All the craters look much like the volcanic craters that are found on earth.

M. Some craters have a number of light-colored streaks, called **rays**, that radiate in all directions.
   1. The most conspicuous rays come from the crater called **Tycho**.
   2. Because the rays throw no shadow, they must be made by a material spread out over the moon's surface.

N. There are two common theories about how the craters were formed.
   1. The **volcanic theory** proposes that they are the craters of extinct volcanoes that were active a long time ago.
   2. The **meteorite theory** proposes that they were formed by large meteorites that struck the moon's surface.

O. The meteorite theory is weakened by the fact that no new craters have been formed since the moon has been observed by telescope, even though the moon is being continually bombarded by meteorites.

P. The moon's surface is also covered with many cracks, called **rills**.
   1. They are usually about one-half mile wide and of unknown depth.
   2. Some rills are crooked, but others run in a straight line for many miles.

III. The Motion of the Moon Around the Earth

A. The moon travels around the earth in a path, or orbit, that is shaped like an ellipse.

B. The moon moves or revolves around the earth in a counterclockwise direction (from west to east), which is the same direction as the earth revolves around the sun.

C. Because the moon's orbit is elliptical, the moon comes a little closer to the earth on one side of its orbit than on the other side.

1. The point of its orbit nearest the earth is called its **perigee**, and the point of its orbit farthest away from the earth is called its **apogee.**
2. At perigee the moon is about 220,000 miles from earth.
3. At apogee the moon is about 250,000 miles from earth.
4. The moon's average distance from earth is about 240,000 miles.

D. The moon keeps revolving around the earth because two forces are acting on the moon at the same time.
1. These two forces are the same forces that keep the planets revolving around the sun.
2. One force is the earth's **pull of gravity** on the moon, which would make the moon rush to the earth if this were the only force acting on the moon.
3. The other force is caused by **inertia,** which would make the moving moon travel straight into space away from the earth if this were the only force acting on the moon.
4. However, both inertia and gravity act on the moon at the same time and in such a way that the moon travels neither straight into space nor toward the earth, but around the earth instead.

E. The moon revolves around the earth at a speed of about 2200 miles an hour.

F. The time needed for the moon to revolve once around the earth is called the **lunar month.**
1. It actually takes the moon 27⅓ days to revolve once around the earth.
2. However, because the earth is revolving around the sun at the same time, the moon seems to take a longer time to revolve once around the earth.
3. It takes 29½ days for the moon to go from one full moon to the next.
4. Calendars use 29½ days as the time for one lunar month.

G. The moon rises about 50 minutes later each day.
1. This difference in rising time happens because the moon moves in its orbit in the same direction (counterclockwise) as the earth rotates.
2. Therefore, it takes the earth a little longer each day to turn around so that the moon can be seen farther in its orbit.

H. The moon rotates on its axis in a counterclockwise direction (from west to east).
1. It takes the moon just as long to rotate once on its axis as it does to revolve once around the earth.
2. This rotation time means that the moon's day is just as long as its month.
3. Thus, the moon has about two weeks of daylight at one time, followed by about two weeks of nighttime at one time.

I. Because the earth rotates in a counterclockwise direction (from west to east), the moon seems to rise in the east, move across the sky, and set in the west.

J. Like the sun, the moon looks bigger when it is rising or setting.
1. The moon also looks bigger when seen against buildings or other objects on the horizon.
2. It then looks smaller when seen by itself high in the sky.

K. When the moon is rising and setting, it looks yellow or even orange.
1. This phenomenon, as with the sun, happens because rays of red light can pass through the thicker part of the earth's atmosphere much more easily than rays of blue light.
2. When the moon is low on the horizon, the light from the moon must travel a greater distance through the thicker part of the earth's atmosphere than when the moon is overhead.
3. The blue rays in moonlight cannot get through this greater distance of air, and they are reflected and scattered by the dust particles in the air.
4. However, the red rays in moonlight can still get through.
5. The moonlight now has less blue in it, and thus the moon looks yellow or orange.

6. When the moon is high in the sky, all the rays of light can get through this shorter distance of air, and thus the moon looks white.

L. Because of the moon's rotation on its axis only once in a lunar month, all we see is one half of the moon's surface.
  1. Actually we see a little more than one half (about 59 percent) of the moon's surface.
  2. Because the moon's orbit is slightly tilted, we can look a little over the moon's top and under its side as it travels around.
  3. We can also see a little more of each side of the moon because the moon moves faster at perigee than at apogee.
  4. At perigee, when the moon increases its speed, the earth lags behind and we see a little more of one side of the moon.
  5. At apogee, when the moon decreases its speed, the earth moves ahead and we see a little more of the other side of the moon.

M. Earth satellite pictures taken of the other side of the moon seem to show that it is not much different from the side that we can see.

III. Phases of the Moon

A. The moon does not give off light, but it shines because it reflects the light of the sun.

B. Because the moon is so close to the earth, it is the second brightest heavenly body in the sky.

C. The side of the moon that faces the sun is always brightly lighted, but the side that is turned away from the sun is in darkness.

D. The lighted side of the moon cannot be seen in the daylight, except in early morning and late afternoon, because the sun's light is very bright and because the earth's atmosphere scatters the sunlight in all directions.

E. As the moon travels in its orbit around the earth, we see different amounts of the moon's lighted surface.

F. These changes in the amount of lighted surface that we see are called the phases of the moon.

G. During the calendar lunar month, when the moon makes one complete revolution around the earth in 29½ days, the moon passes through all its phases, going from completely dark to completely bright, and then back to completely dark again.

H. When the moon is between the earth and the sun, the dark side of the moon is turned toward the earth and we cannot see the moon at all.
  1. This phase is called the **new moon.**
  2. Sometimes the new moon can be seen faintly because it is lighted by earthshine, which is sunlight reflected from the earth onto the moon.
  3. The new moon rises at sunrise and sets at sunset.

I. About one or two days later, as the moon continues to revolve from west to east around the earth, a little of the lighted side of the moon can be seen on earth.
  1. The part of the moon that can now be seen is shaped like a thin **crescent.**
  2. The rest of the dark part of the moon can be seen faintly because of the earthshine.

J. About one week after the new moon, one half of the lighted side of the moon can be seen on earth.
  1. This phase is called the **first quarter,** or **half moon.**
  2. The first quarter rises at noon and sets at midnight.

K. A few days later almost all of the moon's lighted side can be seen on earth, and this phase is called the **gibbous moon.**

L. About two weeks after the new moon, all of the lighted side of the moon can be seen.
  1. This phase is called the **full moon.**
  2. Now the earth is between the moon and the sun.
  3. At full moon, the moon has made one

half of one complete revolution around the earth.
4. The full moon rises at sunset and sets at sunrise.

M. When the moon goes from new moon to full moon and the amount of lighted surface that we see grows larger, we say the moon is **waxing**.

N. When the moon goes from full moon to new moon and the amount of lighted surface that we see grows smaller, we say that the moon is **waning**.

O. About one or two days after the full moon, the amount of the lighted side that we can see grows smaller, or wanes, and we see a gibbous moon again on earth.

P. About one week after the full moon, only one half of the moon's lighted side can be seen on earth.
1. This phase is called the **last quarter**, or **half moon**.
2. The last quarter rises at midnight and sets at noon.

Q. After the last quarter the moon wanes even more until it is shaped like a crescent again.

R. About one week after the last quarter, the moon has completed one revolution around the earth and is back in its original position as a new moon.

S. The phases of the moon then start again, with the moon waxing until it becomes a full moon and then waning until it is a new moon again.

IV. The Moon Causes Tides

A. **Tides** are the rise and fall of the oceans caused by the moon's pull of gravity on earth.
1. The earth has a pull of gravity on the moon, and at the same time the moon has a pull of gravity on the earth.
2. Because the earth is larger and heavier than the moon, its pull of gravity on the moon is greater than the moon's pull of gravity on the earth.
3. The earth's stronger pull of gravity helps keep the moon revolving around the earth.
4. The moon's weaker pull of gravity affects the earth in the form of tides.

B. Tides are formed because the moon's pull of gravity on the side of the earth facing the moon makes the easily movable waters of the earth on that side bulge out toward the moon.
1. This watery bulge is called a **high tide**, or **flood tide**.
2. Because this tide is on the side of the earth facing the moon, it is also called the **direct tide**.

C. At the same time another high tide is formed on the opposite side of the earth.
1. This tide is formed because the moon not only pulls on the earth's waters nearest it, but also pulls hard on the solid part of the earth.
2. This pull leaves the water on the opposite and farthest side, where the moon's pull of gravity is weakest, bulging out behind to form another high tide.
3. Because this tide is on the opposite side of the earth, away from the moon, it is called the **opposite tide**.

D. The water that is drawn in to make bulges at these two points on earth comes from the remaining water at the opposite two points on earth.
1. The water at the opposite two points now flattens out and forms lower levels.
2. These lower levels are called **low tides**.

E. Because the earth rotates on its axis once every 24 hours, the earth has two high tides and two low tides every 24 hours at different points of the earth.

F. The tide rises for about 6 hours; then it falls or ebbs for about 6 hours.

G. Because the moon rises about 50 minutes later each day, high tide and low tide also are about 50 minutes later each day.

H. When the moon is at perigee, about 30,000 miles closer to the earth than at apogee, the moon's pull of gravity on the earth becomes greater so that the tides are higher and lower than usual.

I. The sun's pull of gravity on the earth also causes tides on earth.
   1. However, because the sun is so much farther away from the earth, the sun's tides are weaker than the moon's tides.
   2. The sun produces tides that are a little less than half as big as the tides produced by the moon.

J. When the sun is in line with the moon, very high and very low tides are formed.
   1. These tides occur because the sun and the moon combine their pull of gravity on the earth.
   2. The sun and moon are in line with each other twice a month, at new moon and at full moon.
   3. These very high and very low tides are called **spring tides.**

K. When the sun and moon are at right angles to each other, tides that are not as high or as low as usual are formed.
   1. These tides occur because the sun's pull of gravity and the moon's pull of gravity are now working against each other.
   2. The sun and the moon are at right angles to each other twice a month, at first quarter and at last quarter.
   3. These smaller high and low tides are called **neap tides.**

L. The rise in tides differs at different parts of the earth, depending upon the kind of shoreline and ocean floor found at each part.
   1. On the open sea the rise in tides is only 2 or 3 feet.
   2. At Cape Cod Bay the rise in tides may be 10 feet at times.
   3. At the Bay of Fundy the narrow bay can produce tides that rise more than 50 feet.

M. If man knows when the tides will be high and low, this knowledge can be useful to him.
   1. For some channels, ships arrive and leave only at high tide when the channel is deep enough to allow the ships to come and go safely.
   2. Ships like to leave port when the tide is going out so that they do not have to fight a tide that is coming in.
   3. People like to go swimming at high tide rather than at low tide.

V. Eclipses

A. As the sun shines on the earth and the moon, both throw a long shadow into space.
   1. The earth's shadow is about 866,000 miles long.
   2. The moon's shadow is about 240,000 miles long.

B. We have night on earth because we are carried around by the earth's rotation into the earth's own shadow.

C. At certain times the moon passes between the earth and the sun in such a way that people on earth cannot see the sun.
   1. This phenomenon is called an eclipse of the sun, or a **solar eclipse.**
   2. An eclipse of the sun happens only when there is a new moon, where the moon is between the earth and the sun.

D. In a solar eclipse the moon's shadow falls on the earth.

E. The shadow of the moon on the earth has two parts.
   1. There is a cone-shaped inner part, called the **umbra,** which is completely dark.
   2. There is also a broader outer part, called the **penumbra,** in which the light is only partially blocked.

F. The tip of the umbra only covers a very small part of the earth's surface so that only this small part of the earth's surface is in complete shadow or darkness.
   1. People who are inside the umbra see the sun become completely covered and blotted out from view.
   2. When the sun's light is completely cut off, we say that a **total eclipse** of the sun has taken place.
   3. At any given spot on earth, a total eclipse lasts about 8 minutes.
   4. During a total eclipse, the sun's corona can be seen.

G. The penumbra covers a much larger part of the earth's surface.
   1. People who are inside the penumbra see only part of the sun covered and blotted out from view.
   2. When the sun's light is only partially cut off, we say a **partial eclipse** of the sun has taken place.

H. Sometimes, especially if the moon is near apogee and the moon is in the right position to produce a solar eclipse, the moon's umbra may be too short to reach the earth's surface.
   1. When this phenomenon happens, the sun is still eclipsed, but not completely; it shows a thin ring of light around the edges.
   2. This kind of solar eclipse is called an **annular** or **ring eclipse**.

I. Total eclipses of the sun do not happen very often.
   1. For a total eclipse of the sun, the moon must be in an exact line between the sun and the earth when the moon reaches the new moon phase.
   2. This position is not reached very often, because the moon's orbit is tilted a little; consequently the moon usually passes between the earth and the sun either too high or too low for its shadow to fall on the earth.

J. Sometimes the earth passes between the sun and the moon in such a way that the earth cuts off the sunlight that the moon reflects, and the moon cannot be seen.
   1. This phenomenon is called an **eclipse of the moon**, or a **lunar eclipse**.
   2. An eclipse of the moon occurs only when there is a full moon, where the earth is between the moon and the sun.

K. In a lunar eclipse the earth's shadow falls on the moon.
   1. The moon passes quite often through the earth's rather large penumbra so that a partial eclipse of the moon happens quite often.
   2. However, because the moon's orbit is tilted, the moon does not pass through the earth's umbra very often so that a total eclipse of the moon is quite rare.

BEYOND THE SOLAR SYSTEM

I. The Stars

A. Stars are suns in space, and they produce their own light.

B. There are countless stars in the sky, and about 3000 can be seen with the naked eye.

C. Stars are not in a fixed position, but they are moving rapidly through space in all directions.

D. Stars differ in size.
   1. Small stars, like the sun, are called **dwarfs**.
   2. Large stars, like Aldebaran and Pegasi, are called **giants**.
   3. Tremendously large stars, like Antares and Betelgeuse, are called **supergiants**.

E. Stars differ in color, depending upon their age and temperature.
   1. As the stars become older, their surfaces become cooler so that the stars change color.
   2. The youngest stars are blue-white or white, and they have surface temperatures of 40,000 to 60,000 degrees Fahrenheit.
   3. Yellow stars have surface temperatures of about 10,000 degrees Fahrenheit.
   4. Orange stars have surface temperatures of about 6000 to 8000 degrees Fahrenheit.
   5. Red stars are the oldest stars, and they have surface temperatures of about 3000 to 6000 degrees Fahrenheit.

6. Our sun is classified as a yellow star.

F. The brightness of a star depends upon its temperature, size, and distance from the earth.
1. Astronomers call the brightness of a star its **magnitude.**
2. The brighter the star, the smaller the magnitude number it will have.
3. **First-magnitude** stars are the brightest stars.
4. A first-magnitude star is two and one-half times as bright as a second-magnitude star.
5. A **second-magnitude** star is two and one-half times as bright as a third-magnitude star, and so on.
6. The faintest stars that the eye can see are **sixth-magnitude** stars.
7. Stars with a **twenty-third magnitude** have been seen with the telescope.

G. **Variable** stars are stars that flare up and become brighter, and then grow dimmer again.
1. For some stars this happens because the star has exploded.
2. For other stars this change in brightness happens because they grow larger and shrink regularly.

H. A **nova,** or "new star," is a dim star that suddenly becomes thousands of times more brilliant than it was before.
1. A nova is not really a new star, but it only seems to be new because it has suddenly become so conspicuously bright.
2. Occasionally, an unusually bright nova, in this case called a **supernova,** will appear in the sky.
3. Astronomers do not know the exact cause of a nova.

I. **Double** stars, also called **binary** stars, are two stars that are held very closely together by their pull of gravity on one another.

J. In some cases whole groups of stars, called **star clusters,** are held together by their pull of gravity on one another.
1. Some star clusters are made up of a few stars that are moving in parallel paths.
2. Other star clusters are loose collections of stars, and they are called **open clusters.**
3. **Globular clusters** are shaped like a ball or globe, and they have as many as 100,000 stars in them.
4. Clusters that are so large and thick with stars that they look like shining clouds are called **star clouds.**

K. Although stars seem to twinkle, they really do not.
1. The stars are so far away that they are only small dots of light when we look up at them.
2. Movements of the earth's air make the thin rays of light from these distant stars move back and forth, or twinkle.

L. Planets do not twinkle.
1. The planets are nearer the earth and their rays of light are thicker.
2. Movements of the earth's air do not affect these thicker rays of light.

II. CONSTELLATIONS

A. Long ago, astronomers divided the stars into groups, which made it easier to describe where a heavenly body was.

B. These groupings of stars are called **constellations.**

C. The constellations were named after gods, legendary heroes and heroines, animals, and objects.

D. Most of the constellations do not look like the persons, animals, or objects after which they were named.

E. The movement of the earth as it turns on its axis makes the constellations seem to move through the sky as if they were on a transparent globe surrounding the earth.
1. If the earth's axis were extended into space, it would also become the axis for this imaginary globe.
2. In the earth's northern hemisphere all the constellations seem to move around a point, called the **celestial north pole,**

that is directly above the earth's north pole.

3. In the southern hemisphere all the constellations seem to move around a point, called the **celestial south pole**, that is directly above the earth's south pole.
4. A star located directly on the celestial north or south pole would not seem to move.
5. The North Star, called **Polaris**, is so close to the celestial north pole that it does not seem to move at all.
6. Polaris is the last star in the handle of the Little Dipper, which is part of the constellation called the **Little Bear**.
7. All the constellations in the northern hemisphere seem to revolve around Polaris.

F. Because the earth is in different positions as it revolves around the sun, different constellations are seen at different times of the year.

G. Also, persons living in the northern hemisphere see constellations that are different from those seen by persons living in the southern hemisphere.

III. The Zodiac

A. The sun's path among the stars during 1 earth-year is called the **ecliptic**.

B. A strip of sky a little above and below the sun's path or ecliptic is called the **zodiac**.

C. Special names have been given to 12 star formations, one for each month of the year, in the zodiac.

1. These special star formations are known as the "signs of the zodiac."
2. In any month, an observer on earth can look toward the sun and see one particular sign of the zodiac facing him.

IV. Galaxies

A. A **galaxy** is a large collection of stars, dust, and gas, all held together in a group by the pull of gravity.

B. The sun and the solar system are part of a galaxy called the **Galaxy**.

C. Part of the Galaxy, called the **Milky Way**, can be seen each night.

1. The Milky Way is a broad band of light stretching across the sky.
2. There are millions of stars in the Milky Way, and their light makes a milky band in the sky.

D. The Galaxy has billions of stars in it, and it has a shape that is somewhat like a flattened, circular wheel.

1. The distance across the wheel is about 100,000 light years, which is the distance light would travel for 100,000 years.
2. There are three spiral arms that curve out from the center of the Galaxy.

E. The whole Galaxy is rotating around its center at a tremendous speed.

1. All the stars in the Galaxy rotate in the same direction, but at different speeds.
2. The sun and the solar system are about 26,000 light-years from the center, or about halfway between the center and the rim of the Galaxy.
3. The sun and the solar system are moving at a speed of about 140 miles a second in a circular orbit around the center of the Galaxy.
4. The stars at the rim of the Galaxy are moving about four times as fast.
5. It takes the Galaxy about 200 million years to rotate once around its center.

F. A **nebula** is a great cloud of dust in a galaxy.

1. There are many nebulae in each galaxy.
2. Nebulae do not give off any light of their own.
3. Some nebulae are easily seen because they reflect the light of nearby stars.
4. Other nebulae are dark because they either cut off the light from stars behind them or because there are no stars nearby to light them up.

G. There are more than a billion galaxies beyond the Galaxy, all rotating at tremendous speeds.

H. Galaxies are usually found in three shapes: irregular, spiral, and elliptical.

I. Irregular galaxies have many blue-white giant stars in them and are probably young galaxies.

J. Spiral galaxies have a number of spiral arms extending from their centers.
   1. There are blue-white giant stars in the arms and red stars toward the center.
   2. Many astronomers think that a spiral galaxy forms from an irregular galaxy.
   3. As the galaxy rotates, spiral arms form and direct the younger blue-white stars toward the center of the galaxy.

K. Elliptical galaxies are shaped like an oval or ellipse and are smaller than spiral galaxies.
   1. Most of their stars are the older yellow and red stars.
   2. Many astronomers think that an elliptical galaxy forms from a spiral galaxy, where all the stars in the spiral arms have been gathered into the main body of the galaxy.

V. The Universe Is Expanding

A. To astronomers the universe seems to be a tremendous expanse of space that is at least 10 billion light-years across.

B. Scattered over this space are millions of galaxies.

C. Most galaxies are separated from their neighbors by millions of light-years of space.

D. Astronomers believe that the galaxies are all moving away from each other at high speed.
   1. The galaxies that are farther away from us seem to be traveling faster than those nearer to us.
   2. Some of these galaxies are moving at a speed of more than 30,000 miles a second.

E. This high speed means that the space between the galaxies is steadily increasing, but the galaxies themselves remain the same size.

VI. How Distances in the Universe Are Measured

A. Until recently, astronomers measured the vast distances in the universe by using a unit of measurement called the light-year.
   1. Light travels through space at a speed of about 186,000 miles a second.
   2. A light-year is the distance that light travels for 1 year.
   3. A light-year is about 6000 billion miles.

B. Now astronomers use another unit of measurement, called the parsec.

C. A parsec is about 3⅓ light-years, or about 19,000 billion miles.

VII. How the Universe Is Studied

A. Scientists use different kinds of instruments to study the heavenly bodies that make up the universe.

B. The oldest types of instruments used have been the telescopes.

C. Two kinds of telescopes are used: the refracting telescope and the reflecting telescope.

D. The refracting telescope is made up of a hollow tube with convex lenses at each end.
   1. Rays of light from a planet or a star enter one lens of the telescope and are bent to form a small image of the planet or star.
   2. This image is then magnified by the other lens in the telescope.
   3. The largest refracting telescope, having lenses 40 inches in diameter and weighing 500 pounds, is at Yerkes Observatory in Wisconsin.
   4. Refracting telescopes cannot be made with lenses larger than 40 inches in diameter because the lenses must be supported at the rims, and larger lenses are so heavy that they sag out of shape from their own weight.

E. The reflecting telescope uses a large, curved mirror instead of a lens to collect the rays of light from a planet or star and produce an image.

1. Rays of light from a planet or star are collected by a large, curved mirror in the telescope to form a small image of the planet or star.
2. This small image is then magnified by a convex lens in another part of the telescope.
3. The largest reflecting telescope, having a diameter of 200 inches and weighing 14½ tons, is the Hale telescope on Mount Palomar in California.
4. A reflecting telescope can be made much larger than a refracting telescope because the mirror can be supported from behind.
5. The very large mirror of a reflecting telescope helps gather and focus more light than the smaller lens of the refracting telescope.
6. With a reflecting telescope, stars more than two billion light-years away can be seen.

F. Astronomers rarely look through a telescope with their eyes; instead they use a camera that is attached to the telescope.

1. The human eye tires after a while, is not sensitive to colors when the light is dim, and cannot build images into stronger or larger ones.
2. On the other hand, the camera always works well and can use film that is very sensitive to colors and dim light.
3. The camera can also take pictures over a period of several minutes or even hours, and in this way it builds up weak images into stronger ones.
4. At the same time the photograph becomes a permanent record of the observation that was made, and it can be studied again and again.

G. Telescopes are mounted on a platform so that astronomers can take a picture of a star over a long period of time.

1. The platform always rotates at the same rate as the earth, but in the opposite direction.
2. This rotation makes the star seem to stay in the same position so that a strong, clear picture can be produced instead of a streak of light.

H. The air above the earth presents a problem to astronomers when they use telescopes.

1. The rays of light from the stars must pass through the air above the earth before they reach the telescope.
2. The air is always moving, which makes these rays bend back and forth, so that the stars seem to twinkle and cannot be seen sharply and clearly.
3. The air also has dust and water vapor in it, which dims the light rays from the stars.
4. If the telescopes are built high on a mountain, this location helps very much because the air higher up is thinner and has less dust and water vapor in it.

I. Temperature is also a problem to astronomers using telescopes.

1. Changes in temperature make the mirrors, lenses, and other parts of the telescope expand and contract.
2. The expansion and contraction makes the telescope operate differently from one time to another.
3. The astronomers have to adjust the telescope all the time and make corrections in their observation.

J. The **radio telescope** is able to study objects too far away to be seen with ordinary telescopes by detecting the radio waves these objects give off.

1. Radio telescopes have very sensitive receivers with very large antennas that can be pointed to any spot in the sky.
2. The antennas usually have large metal "mirrors," shaped like a bowl, that gather and focus the radio waves in the same way as the curved mirrors in reflecting telescopes gather and focus light rays.
3. The largest radio telescope, built by the United States Navy in Sugar Grove, West Virginia, is about 600 feet across.

K. Another important instrument that astronomers use is the **spectroscope**, which finds out what chemical elements there are in the planets and stars.

1. Light rays that enter the spectroscope pass through a prism, which breaks the light up into the colors of the spectrum.
2. Bright and dark lines can be seen in the different colored bands of the spectrum.
3. These lines always appear when certain chemicals are present in glowing gases that give off light.
4. The position and width of the lines in the different colored bands tell us what elements are present.
5. By comparing the position and width of the lines in a spectrum produced from the light of a star with those produced from the glowing gases of chemical elements that we already know, astronomers can tell what chemical elements are in the particular star.
6. Astronomers have found that the sun, planets, and most of the stars have the same kinds of elements as those found on earth.
7. Helium was first discovered in the sun by a spectroscope before it was found on earth.

LEARNING ACTIVITIES FOR "THE UNIVERSE"

THE SUN

1. *The size of the sun* · Show how much larger the sun is than the earth. Draw two circles on the chalkboard, one with a diameter 13⅝ inches wide and the other with a diameter ⅛ inch wide. The diameter of the larger circle, labeled *sun*, will be 109 times larger than the smaller circle, labeled *earth*. Place the circles 93 inches apart. By letting 1 inch equal 1 million miles, 93 inches would indicate the distance of the earth from the sun. If the sun were a hollow ball, more than one million earths would fit inside it.

2. *Source of the sun's energy* · Describe and discuss the nuclear reaction that is continually taking place inside the sun. Compare this reaction with that of a hydrogen bomb, which lasts only for a moment. Point out the difference in temperature at the surface and at the center of the sun.

3. *The parts of the sun* · Discuss the parts of the sun: the hot gases that make up the body of the sun, the layer of the photosphere, the red chromosphere above it, and the silvery corona surrounding the chromosphere. Look for a photograph of a solar eclipse that shows the corona quite clearly. Also, look for photographs showing sunspots and solar prominences.

4. *Observe sunspots* · Arrange a telescope or binoculars (at least six-power) so that it is pointing directly at the sun (Figure 9–1). This arrangement can be made by getting a cardboard carton 3 feet long, 2 feet wide, and 1 foot high. One side of the carton should be open to

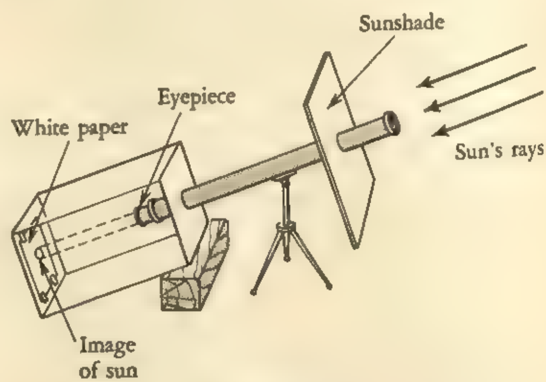


FIGURE 9–1.
ARRANGEMENT FOR OBSERVING SUNSPOTS.

allow the sunspots to be easily seen. Prop the carton on a box or other carton in such a way that the rear end is facing the sun's rays directly. In the front end of the carton make a hole large enough for the eyepiece end of the telescope or binoculars to be inserted.

If a telescope is used, make just one hole, and also make a large cardboard sunshade for the barrel of the telescope. If binoculars are used, make two holes and fasten the binoculars securely with tape to the box. Cover one of the outer binocular lenses with dark paper so that only one image of the sun will be produced inside the carton. A sunshade is not necessary when binoculars are used.

Now adjust the eyepiece of the telescope or binoculars until there is a sharp, clear image of the sun on the inside rear end of the carton. A sheet of white paper that is taped on the rear end will make the image more easily visible. The sunspots will appear on the sun's image as small, dark marks near the equator. Observe the sunspots every day at the same time. They will slowly move across the sun as the sun rotates. Note that they appear only on or near the sun's equator and never at the poles. If the sunspots seem to be moving from west to east (instead of east to west), this is because of the way the astronomical telescope operates. Also, the sunspots will be upside down.

(*Note: Do not look directly at the sun through the telescope or binoculars! You can permanently damage your vision in this way!*)

THE SOLAR SYSTEM

1. *Make a chalkboard diagram of the sun and the planets* · Compare the size of the planets with each other and with the sun, and also show their relative distances from the sun. To get the correct relative sizes and distances, use a model of the sun that is 27 inches in diameter, and let 1 inch represent 20 million miles. On this basis, Table 9–1 shows the proper size and distance for each planet.

TABLE 9–1. Dimensions and Distances for a Chalkboard Diagram of the Sun and Planets.

BODY	DIAMETER	DISTANCE
Sun	27″	—
Mercury	1/8″	1 3/4″
Venus	1/4″	3 1/4″
Earth	1/4″	4 3/4″
Mars	1/8″	7″
Jupiter	2 3/4″	2′
Saturn	2 3/8″	3′ 8″
Uranus	1″	7′ 5″
Neptune	7/8″	11′ 8″
Pluto	1/8″	15′ 3″

Cut out a large cardboard or paper circle, 27 inches in diameter, and write the word *sun* in large letters across its surface. Tape this circle to one end of the chalkboard. Now draw circles on the chalkboard, each circle representing a planet. Give each circle its proper size and place it at the proper distance from the sun, as shown in Table 9–1. If the chalkboard is not wide enough, cut out paper circles and tape them on the wall beside the chalkboard. Be sure to insert a large number of dots between Mars and Jupiter to show the presence of the asteroids. Write on the chalkboard, as close to the planets as possible, such pertinent information as the name of the planet, its actual size, its distance from the sun, and the number of moons it has.

2. *The orbits of the planets are ellipses* · Place a sheet of white paper on a broad, flat piece of wood. Hammer two long carpet tacks or small nails, placed 2 inches apart, into the

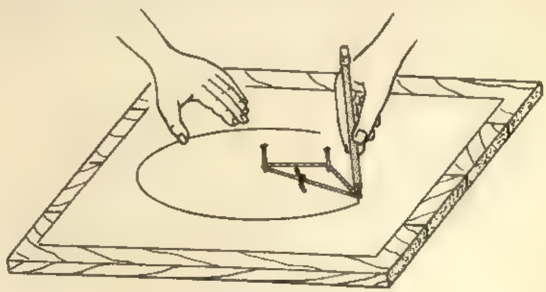


FIGURE 9–2.
DRAWING AN ELLIPSE.

paper and wood (Figure 9–2). Place a loose loop of string around both nails. Stretch the loop as far as possible by holding a pencil point vertically against the string inside the loop. Now, while keeping the string as tight as possible and the pencil point vertical, move the pencil point all the way around the loop of string. The pencil will draw an ellipse. This ellipse will almost be a circle, and it will be very much like the orbit of the earth around the sun. Repeat the experiment, either using a longer loop of string or moving the tacks farther apart, and the ellipse will be more oval in shape.

3. *We see planets by reflected light* · Darken the room. Let a rubber ball represent a planet. The "planet" can barely be seen in the darkened room. In a closet or room that can be completely darkened, the "planet" cannot be seen at all. Let a lighted flashlight represent the sun. When the "sunlight" of the flashlight shines on the "planet," the "planet" can now be seen because the light is reflected to the eye. Planets do not give off their own light. They can be seen because they reflect the light given off by the sun, which is a star.

4. *Why planets revolve around the sun* · Attach a string that is 3 feet long to a tennis ball, rubber ball, or a chalkboard eraser. Hold one end of the string in your hand and whirl the ball around your head. Then let go of the string suddenly and note how the ball travels out in a straight line as it obeys Newton's first law of motion. Whirl the ball around your head again. Note how your hand must pull inward on the string so that the ball will travel around in a circle and not fly out. This pull on the string corresponds to the pull or force of gravity, whereas the tendency of the ball to fly out and travel in a straight line corresponds to the force due to inertia.

Both forces act on a planet so that the planet neither falls toward the sun nor flies straight out into space, but travels around the sun instead. Draw a diagram on the chalkboard to illustrate this action (Figure 9–3). Be sure to make the arrow representing the force due to gravity small (because of the planet's great distance from the sun), and the arrow representing the force due to inertia long. This diagram will show why the resulting arrow, representing the actual path of the planet, is nearer the arrow representing inertia and not halfway between both arrows or nearer the arrow representing gravity. Where the resulting arrow ends, draw another circle to represent the planet, and draw arrows representing the continued action of both forces on the planet. By drawing these arrows and circles at various points, it will be shown why the planet travels around the sun.

5. *Gravity* · Let a ball drop to the ground. The earth's gravity pulls the ball to the ground. Jump into the air. Earth's gravity pulls you down. Both you and the ball have a pull of gravity on the earth, but the earth's pull of gravity is greater. Have a child stand with his hand stretched out, palm up. Place a heavy

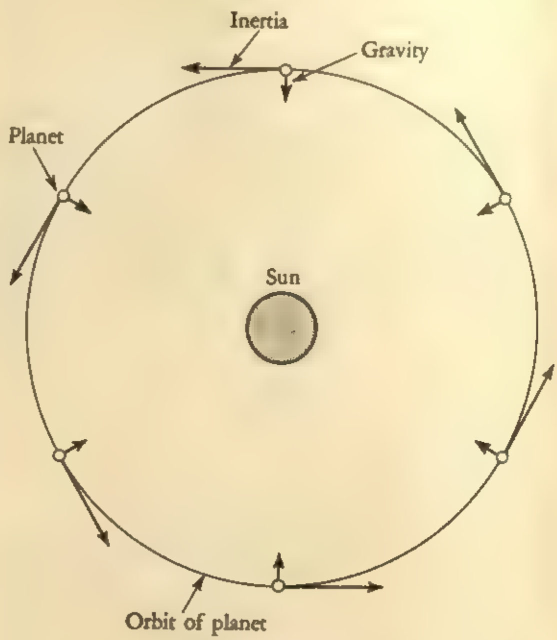


FIGURE 9–3.
GRAVITY AND INERTIA TOGETHER ACT ON A PLANET IN SUCH A WAY THAT THE PLANET REVOLVES AROUND THE SUN.

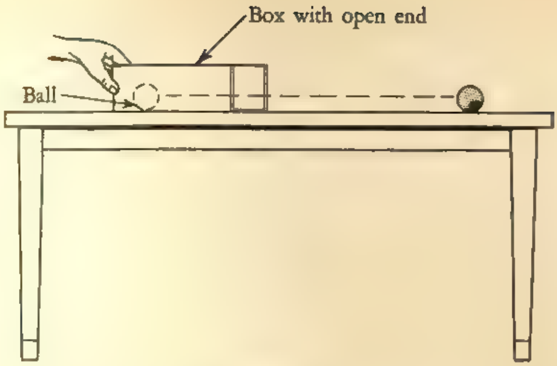


FIGURE 9–4.
INERTIA WILL CAUSE THE BALL TO CONTINUE TO TRAVEL IN A STRAIGHT LINE.

book on the child's palm. He will soon feel the earth's pull of gravity on the book as his muscles work to keep the book in this position.

6. *Inertia* · Remove one end of a shoe box and place a ball in the box. Move the box, with the open end forward, along a long table top and then stop the box suddenly after it has traveled about one third of the distance of the table top (Figure 9–4). The inertia of the ball will make it continue to travel in a straight line on the table top.

Place a 3 × 5 inch index card over the mouth of a glass tumbler. Put a coin on top of the card, positioning the coin so that it is at the center of the tumbler's mouth (Figure 9–5). Now snap the card quickly and suddenly with your finger, and the coin will fall into the

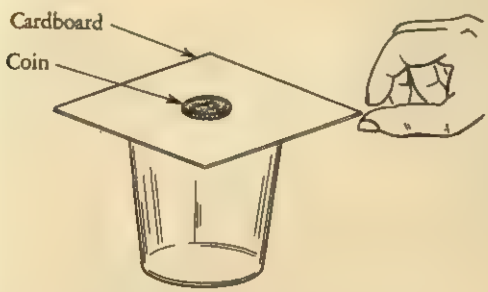


FIGURE 9–5.
INERTIA WILL KEEP THE COIN FROM MOVING WITH THE CARD.

tumbler. Because of its inertia, the coin will stay at rest and not move with the card.

Have the children recall what happened when a car, in which they were riding, stopped suddenly. Their bodies snapped forward because their bodies, which were in motion, tended to stay in motion even though the car had stopped. When the car started again suddenly, their bodies snapped backward because their bodies were at rest and tended to stay at rest even though the car had begun to move.

7. *Observe morning and evening stars* · The morning and evening stars are really planets. Planets, such as Venus and Jupiter, are called morning stars when they are just above the horizon at sunrise and evening stars when they are just above the horizon at sunset. These planets can be easily identified because they are brighter than the real stars at that time. An almanac will indicate which morning and evening stars are visible at any time. Observe these planets each day for a few weeks. Note the time of their appearance and their position.

8. *Show a comet's orbit* · On the chalkboard draw a rough sketch of the orbits of the planets around the sun. Then show the long, oval orbit of Halley's comet, with the sun at one end of the orbit (Figure 9–6). Note how the comet's orbit cuts across the orbits of the planets.

9. *Look for "shooting stars"* · Meteors are very easily seen in the summer, especially in the suburbs and in the country where a comparatively dark and a broad expanse of sky is visible. Also, there are meteor showers that visit the earth annually. These meteor showers are named after the constellations from whose direction the meteors seem to come. Look for the Perseid shower about August 10–14, the Orionid shower about October 20–24, the Leonid shower about November 15–19, and the Geminid shower about December 10–14.

10. *Examine meteorites* · Sometimes it is possible to borrow small meteorites from college, public, or private museums. Have the

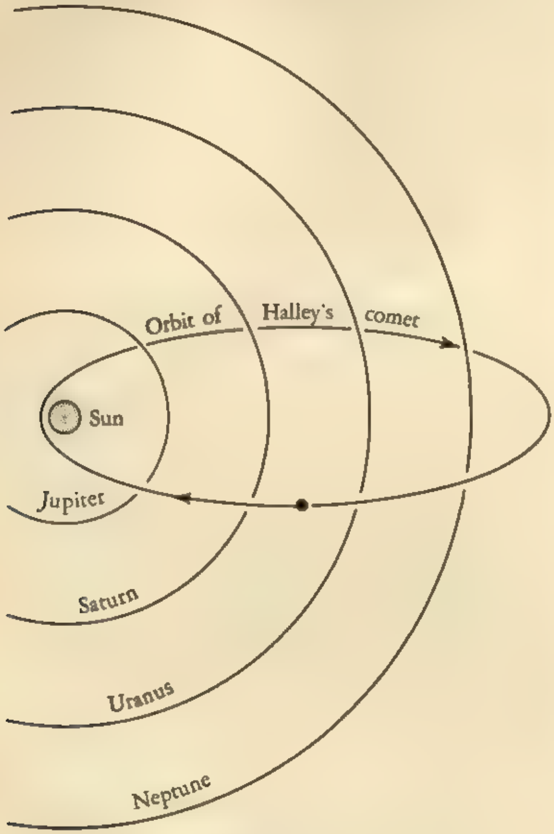


FIGURE 9–6.
ORBIT OF HALLEY'S COMET.

children hold and examine these meteorites that actually came from outer space. Visit museums to look at and find information about larger meteorites. If possible, obtain and show pictures of the Meteor Crater in Arizona or the Chubb Crater in Canada.

11. *How the solar system was formed* · Have the children read the different theories proposed about the formation of the solar system. Promote a discussion of the merits and drawbacks of each theory.

12. *Life on other planets* · Have the children read about conditions, such as temperature, atmosphere, and water, on other planets and discuss the possibility of life, as it exists on earth, on these planets.

EFFECT OF THE SUN ON EARTH

1. *The earth is round* · Show the class a globe of the earth. Proof that the earth is curved can be shown in many ways. A person on land who watches a ship disappear sees the hull disappear first and the smokestacks last. During a lunar eclipse, the earth's shadow on the moon is curved. Photographs taken from jets and rockets at high altitudes show the curvature of the earth clearly. Satellites have already gone around the earth.

2. *The earth's orbit around the sun is an ellipse* · Repeat Learning Activity 2 of "The Solar System" (p. 275), keeping the nails 2 inches apart. Let a gooseneck or table lamp with the shade removed represent the sun. Move a globe of the earth counterclockwise in a complete orbit around the "sun," pointing out that it takes 365¼ days or 1 year to make this orbit.

3. *The earth rotates on its axis* · Push a knitting needle through an orange or a grapefruit. The knitting needle represents the axis, or imaginary line, running through the earth's north and south poles. Tilt the needle slightly and make the orange, which represents the earth, spin or rotate. An excellent analogy of the earth rotating on its axis is the merry-go-round. It turns around and around, and it has a center pole that acts as its axis.

4. *Day and night* · Get a globe of the earth that rotates. This globe will represent the planet Earth. Find out exactly where on the globe you live, then either put a mark or tape a small cutout figure on this spot. Let a source of light represent the sun. You can use a gooseneck or table lamp with the shade removed. Alternate sources of light could be a slide projector or a flashlight.

Now darken the room. Shine the lamp on the globe so that the globe is illuminated evenly by the light (which represents the sunlight). To achieve an even lighting effect, the bulb should be at the same height as the middle of

the globe, and the globe should be moved back and forth until it is in the proper position (Figure 9–7).

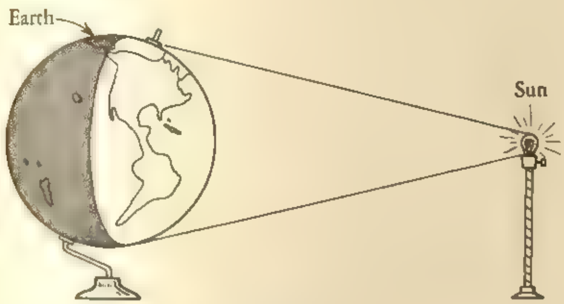


FIGURE 9–7.
THE SUN CAUSES DAY AND NIGHT.

Half the globe will be lighted (daytime) and half the globe will be in darkness (nighttime). Now spin the globe slowly from west to east (counterclockwise when looking down on the north pole from above). The part of the earth where you live will go from day to night and back to day again. Also, the east will receive the light before the west so that, when it is dawn in New York City, it is still dark in Chicago and Los Angeles.

5. *The sun is red at sunrise and sunset* · Draw a diagram to show why the sun is red or yellow at sunrise and sunset (Figure 9–8). The sun's rays must travel a greater distance through the thicker part of the atmosphere when the sun is low on the horizon than when the sun is overhead. The red rays in the sunlight travel through the atmosphere in either case, but the blue rays are scattered, making the sun appear to be orange or reddish.

6. *The earth's axis is tilted* · A globe of the earth that rotates is tilted at an angle of 23½ degrees. Push a knitting needle through an orange or grapefruit. First hold the knitting needle (which represents the earth's axis) vertically, then tilt it about 23½ degrees to show how the earth (represented by the orange or grapefruit) rotates and revolves in this position.

7. *Direct rays and slanted rays* · Darken the room. Shine a flashlight on the inside of the

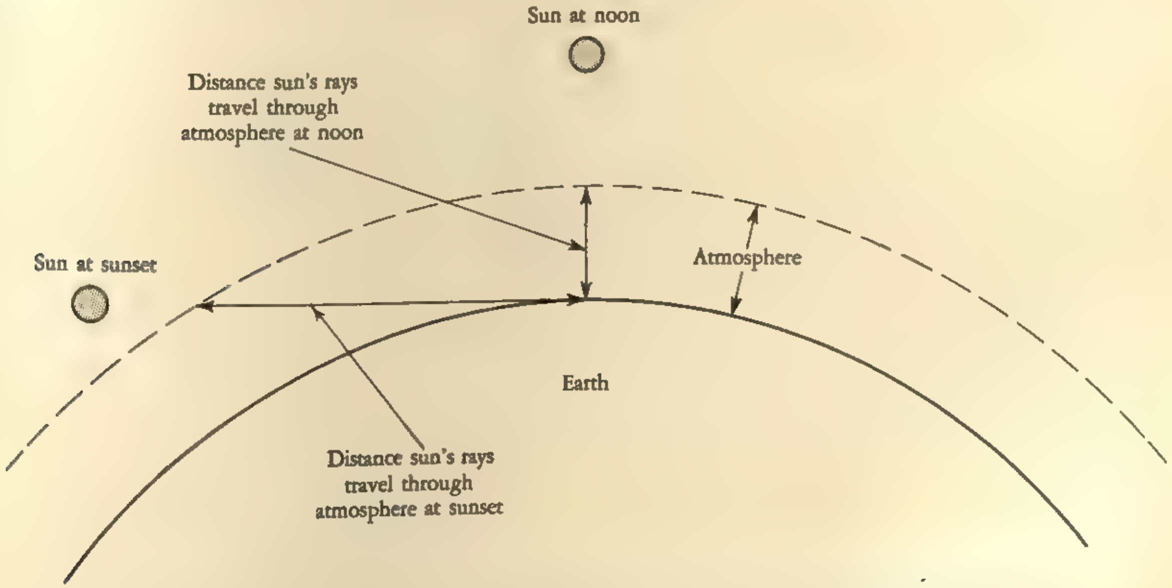


FIGURE 9–8. WHY THE SUN APPEARS RED OR YELLOW AT SUNRISE AND SUNSET.

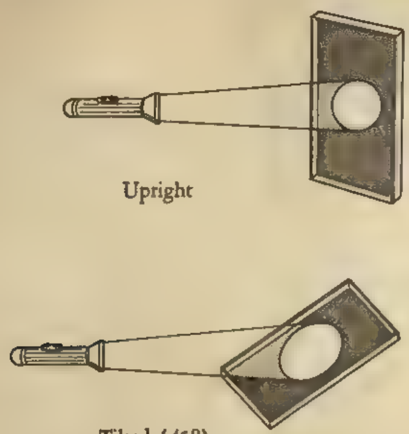


FIGURE 9–9.
DIRECT RAYS ARE MORE CONCENTRATED THAN SLANTED RAYS.

cover of a shoe box that is held vertically upright (Figure 9–9). A small intense circle of light will be produced as the rays shine directly on the cardboard. Now tilt the cardboard cover away from you at an angle of 45 degrees. The same amount of light will be spread out over a larger area and it will not be as bright. By reading a light meter in the morning and at noon, it will also show that the slanted morning rays of the sun are not as intense as the more direct rays of the sun at noon.

8. *The seasons* · Darken the room. Set up a globe of the earth and a gooseneck lamp, and position them as described in Activity 4 above. The globe should be to the left of the lamp with the axis tilted toward the sun (Figure 9–10). This position is the position of the earth when it is summer in the northern hemisphere. The light rays will strike the northern hemisphere vertically and the southern hemisphere at a slant. The north pole will be lighted completely while the south pole will be dark. Spin the globe slowly. The days will be longer than the nights in the northern hemisphere while the nights are longer than the days in the southern hemisphere.

Now move the globe to the other side of the lamp. Conditions will be reversed for both hemispheres. Move the globe to the spring and fall positions. Days and nights are just as long, and the sun's rays strike both hemispheres at the same angle or slant.

9. *The sun seems to change its position during the year* · Note exactly where the sun rises and sets each day, using a building or a tree to fix the position. The sun will rise and set farther to the north during the first half of the year, and farther to the south during the second half. As a result the sun seems to be higher in the sky during the summer. The sun will also strike different parts of the room during the year. This change in position is caused by the earth's movement around the sun.

10. *The sun casts shadows* · Have the children stand with their backs to the sun and observe the shadow that is formed. Let them observe their shadows in the morning, noon, and late afternoon and note the different lengths, depending upon whether the rays strike the body at a slant or vertically.

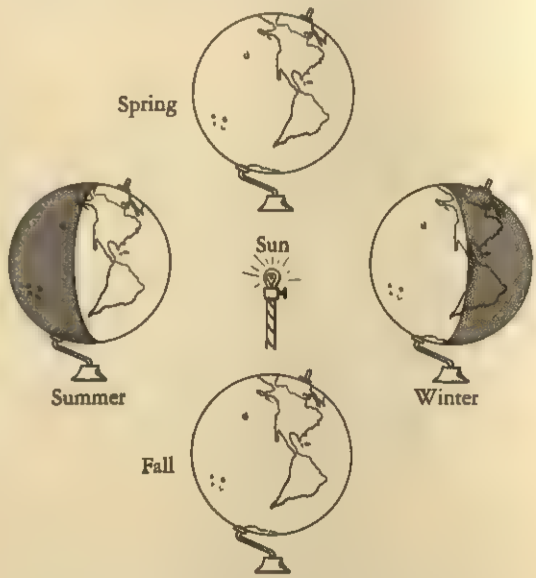


FIGURE 9–10.
THE TILT OF THE EARTH'S AXIS AND THE REVOLUTION OF THE EARTH AROUND THE SUN TOGETHER CAUSE SEASONS ON EARTH.

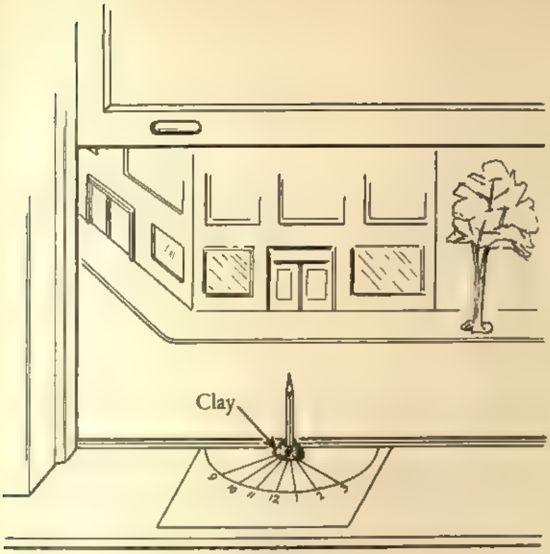


FIGURE 9–11.
A SUNDIAL.

11. *Make a sundial* · Place a short pencil upright in a lump of clay and set the pencil on a piece of blank paper located on a window sill that gets sunlight all day (Figure 9–11). Draw a semicircle around the pencil, using the length of the pencil as the radius and the position of the clay as the center of the circle. The pencil will cast a shadow on the paper. Mark the position of this shadow every hour, drawing a line along the shadow and extending the line until it reaches the semicircle. At the points where the lines reach the semicircle, write down the hour when this shadow occurred. Use this sundial to tell the time on the next sunny day.

12. *Only a small amount of the sun's energy reaches the earth* · Set up a gooseneck or table lamp, without a shade, at one end of a long table and a marble at the other end. Point out that the bulb (which represents the sun) sends out its light in all directions, and the marble (which represents the earth) receives only a very small part of the sun's energy.

13. *The sun is a source of energy* · Select appropriate learning activities from Chapter 11 ("Water, Weather, and Climate"), Chapter 13 ("Plants"), and Chapter 18 ("Heat, Fire, and Fuels") to show that the sun's energy heats the earth, causes weather, makes it possible for plants to manufacture food, and is stored in fuels.

THE MOON

1. *The size and distance of the moon* · Make two balls of clay, one 4 inches in diameter and the other 1 inch in diameter. Place these two balls 10 feet apart. This placement will give a relative idea of the size of the moon and its distance from the earth. The distance of 10 feet is selected because the diameter of the earth is 8000 miles, and the moon's distance from the earth is 240,000 miles, or 30 times the diameter of the earth. Thirty times 4 inches is 120 inches, or 10 feet. Point out that the moon seems so small to us, even though it is one fourth of the size of the earth, because it is so far away from the earth.

2. *The nature of the moon* · When the moon is full, have the children observe the moon through a telescope or a pair of powerful field glasses. Let them try to find the more important craters, plains or "seas," and mountains, and then identify them by consulting a map of the moon.

3. *Characteristics of the moon* · Discuss the prominent features of the moon—its pull of gravity, its temperature, and its lack of atmosphere and water, resulting in the absence of sound and weather.

4. *The moon revolves around the earth* · Repeat Learning Activities 4, 5, and 6 of "The Solar System" (p. 276). Point out that the moon's orbit is almost a circle. Let a tennis ball represent the moon, and move it around a globe of the earth to show the moon's orbit. Be sure to tilt the moon's orbit a little so that the moon passes a little above and below the earth in its travels.

5. *The same side of the moon always faces us* · Make an "X" with white adhesive tape on a large ball, such as a volley ball, that represents the moon. Let one child, representing the earth, sit in the center of the room. Have a second child hold the ball and walk counterclockwise around the first child in a large circle, always keeping the "X" facing the first child's head. It should be obvious to the rest of the children that the moon rotates just once as it makes one revolution around the earth. Therefore the moon shows only one side to the earth at all times.

6. *The moon seems larger when it is just rising or setting* · Although comparison with nearby objects on the horizon makes the rising or setting moon appear to be larger, this phenomenon can be shown to be an optical illusion. Bend a paper clip so that it fits a yardstick snugly, as shown in Figure 9–12. When there is a full moon on the horizon, sight the moon so that it fits exactly within the two ends of the paper clip, pinching or widening the ends if necessary. Look at the moon again through the paper clip later when the moon is higher in the sky. Its size will not have changed at all.

7. *The moon shines by reflected light* · Let a tennis ball represent the moon and the light from a flashlight represent sunlight. Place the ball on a table and darken the room completely.

FIGURE 9–12.
THE APPARENT CHANGE IN THE MOON'S SIZE WHEN IT IS RISING OR SETTING IS AN OPTICAL ILLUSION.

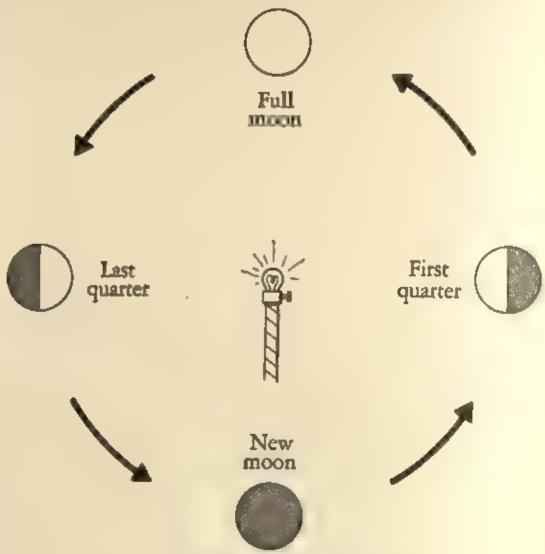


FIGURE 9–13.
PHASES OF THE MOON.

The ball cannot be seen. Then shine the flashlight on the ball. The ball can now be seen because the light from the flashlight strikes the ball and is reflected to the eye. If the room cannot be darkened completely, have the children do the experiment individually at home, using a closet.

8. *Phases of the moon* · Get a styrofoam ball about the size of an orange or grapefruit. These balls are now sold as decorations for Christmas trees, and they have small stems. Remove the shade from a gooseneck or table lamp and turn on the lamp. Place all the children so that they are sitting or standing directly in front of the lamp. Darken the room. Now, while holding the stem of the styrofoam ball, move the ball slowly in a counterclockwise direction around the bulb (Figure 9–13). If the ball does not have a stem, insert one end of a knitting needle into the ball instead.

Start in the new moon position, where the ball (which represents the moon) is directly between the children (who represent the earth) and the lighted bulb (which represents the sun). As the ball moves around the bulb, the

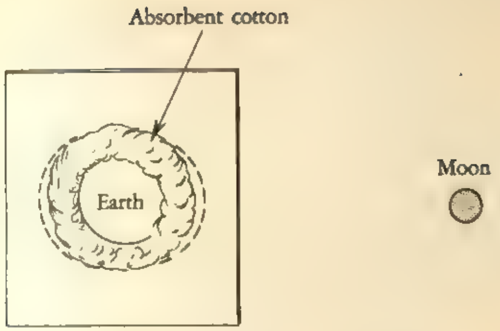


FIGURE 9–14.
THE MOON CAUSES TIDES ON EARTH.

children will be able to see the complete cycle of the phases of the moon.

9. *Tides* · Obtain a piece of white poster board 18 by 24 inches in size, a roll of absorbent cotton, a bottle of blue ink, and some glue or household cement. On the poster board draw a circle 6 inches in diameter, and paint the word *earth* inside the circle. Roll and shape some absorbent cotton until it looks like a doughnut 3 inches thick, which will fit around the circle, and glue the cotton to the poster board (Figure 9–14). After the glue has set, pour the blue ink on the cotton to give the effect of blue waters. Tape the poster board securely to the chalkboard.

Cut out a paper circle 3 inches in diameter and write the word *moon* on it. Also tape the "moon" to the chalkboard to the right of the "earth." Now gently pull the cotton on the side of the "earth" nearest the "moon." A bulge that shows the formation of a high tide will form. Gently pull the cotton on the side farthest from the "moon" to produce a second high tide. The top and bottom of the cotton circle will flatten out to form two low tides.

If you want to show how spring tides and neap tides are formed, cut out another circle and write the word *sun* on it. Place the "sun" to the right of the "moon" and create a spring tide effect with the cotton. Then place the "sun" above the "earth," at right angles to the "moon," and create a neap tide effect with the cotton.

10. *Solar and lunar eclipses* · Let a source of light represent the sun. This source can be a gooseneck or table lamp (with the shade removed), a slide projector, or a powerful flashlight. Get a globe of the earth, and position the globe and light source so that the light falls evenly on the globe when the room is darkened. Let a tennis ball represent the moon. Hold the tennis ball between the "sun" and the "earth" so that a shadow falls on the "earth" (Figure 9–15). The ball may have to be moved back and forth until a sharp shadow forms on the globe. Observers on earth in this shadow would see a solar eclipse.

To show a lunar eclipse hold the tennis ball or "moon" on the far side of the "earth" so that the "earth" is between the "sun" and the "moon." Move the ball back and forth until the "moon" is completely within the earth's shadow, forming a lunar eclipse. Move the ball around the globe in a slightly tilted orbit to show that

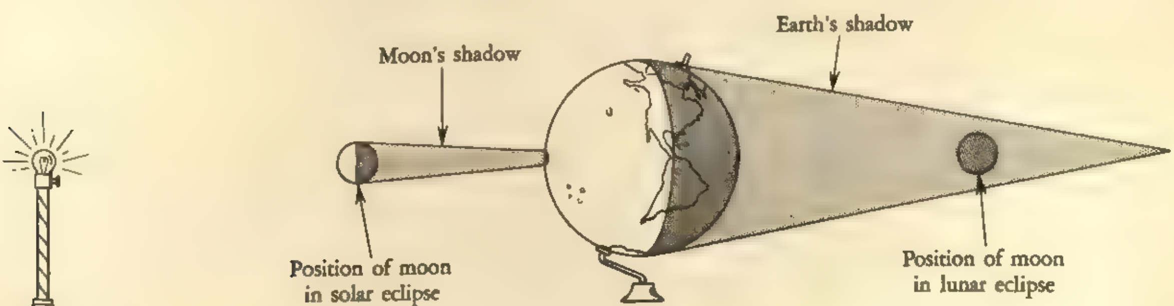


FIGURE 9–15. SOLAR AND LUNAR ECLIPSE.

most of the time the shadows of the moon and earth are either too high or too low to produce an eclipse.

11. *How to watch a solar eclipse* · Get a cardboard carton 3 feet long, 2 feet wide, and 1 foot high. Cut a hole a little larger than the size of your head on one long side of the carton. Tape white paper to one end of the carton. At the other end of the carton cut a small hole 1 inch square, as high as possible and near the long side opposite the side where you cut a hole for your head to enter. Tape aluminum foil over the hole, then make a pinhole in the center of the aluminum foil. Close all four sides of the cardboard carton and tape them securely together to keep out the light.

Now stand with your back to the sun, put your head into the carton, and bend forward until light from the sun enters the pinhole and forms an image on the white paper (Figure 9-16). At no time should you look directly at the sun because it will damage your eyesight permanently.

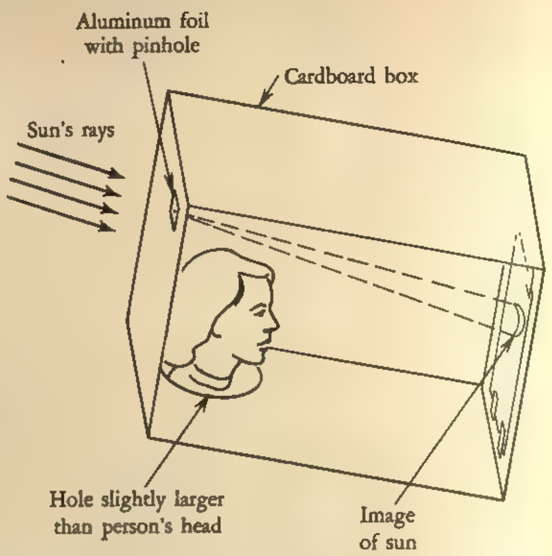


FIGURE 9-16.
ARRANGEMENT FOR OBSERVING A SOLAR ECLIPSE.

BEYOND THE SOLAR SYSTEM

1. *Stars differ in color* · Heat a piece of wire until it glows. It will glow orange at first. Then, as it becomes hotter, it will glow yellow. Turn on a table or gooseneck lamp, with the shade removed, that has a light bulb of clear glass so that the wire inside can be seen. The extremely hot wire will glow a yellowish white. Point out that our hottest stars are blue-white and white, and, as they become cooler, they turn yellow, orange, and then red.

2. *Why stars seem to twinkle* · Form an image of a bright source of light on a screen. This image can be formed by placing a small porcelain socket containing a lighted flashlight bulb on a pile of books. Place the handle of a magnifying glass (convex lens) in a tall lump of clay so that the magnifying glass remains upright in a fixed position. Adjust the height of the magnifying glass so that the center of the lens is the same height as the flashlight bulb in the porcelain socket (Figure 9-17). Place

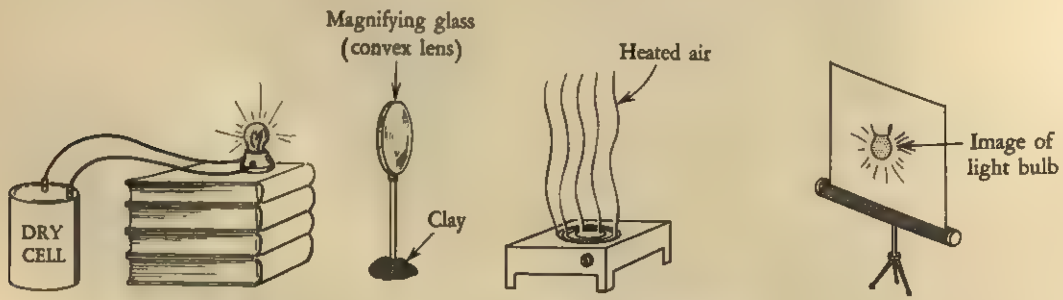


FIGURE 9-17. MOVING AIR MAKES LIGHT RAYS SHIMMER AND TWINKLE.

the magnifying glass in front of the bulb, between the bulb and the screen, and adjust the position of the glass and screen until a clear image of the bulb appears on the screen. Darken the room. Note that the image is fixed, and it does not move or twinkle.

Now place a hot plate close to the lens and below it. Turn on the hot plate; the image will tremble or twinkle, just as a star does, because heat energy from the hot plate makes the air above the hot plate move back and forth. This movement makes the light rays shift back and forth, or twinkle, as well.

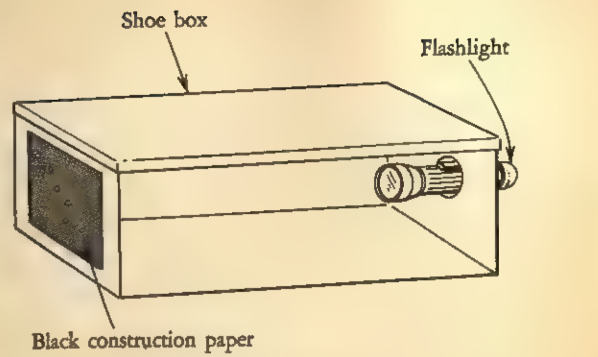


FIGURE 9–19.
A CONSTELLATION BOX.

3. *Find the North Star* · Find the Big Dipper in the sky. The two outside stars of the bowl of the Big Dipper are called the "pointer" stars because they point to the North Star. If a line is drawn through these two stars that continues away from the bottom of the Dipper it will lead you to the North Star (Figure 9–18). The North Star is about five times as far from the "pointer" stars as the distance between the two "pointer" stars. The North Star is at the end of the handle of the Little Dipper. The Big and Little Dippers are always positioned so that, when one is right side up, the other is upside down. Do not expect the North Star to be very bright. It is only moderately bright.

Another way to find the North Star is to find north with a compass. Face north and look halfway up. Stretch your arm and finger to a point halfway between the horizon and straight up (at an angle of 45 degrees). The star you will point to, or the nearest star to where you are pointing, will be the North Star.

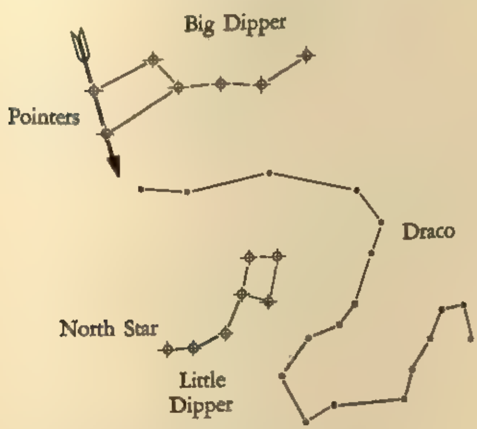


FIGURE 9–18.
FINDING THE NORTH STAR.

4. *Make a bulletin-board exhibit of constellations* · Cover the bulletin board with dark blue paper or cloth, then paste silver stars to show the constellation patterns. White ink can be used, if desired, to draw the figures represented by the constellations. In many popular books on astronomy these constellations are well illustrated. Put up the summer constellations in the early fall, and the winter constellations later in the year. Also, let the children become familiar with the constellations of the zodiac.

5. *Make a constellation box* · Get a shoe box and cut out a large rectangle at one end. Cut up several rectangular sheets from black construction paper, making the sheets slightly larger than the rectangle that was cut out of the box. On each black sheet make pin pricks to form the pattern of one of the common constellations. Tape one of the black sheets over the rectangular hole in the box. At the other end of the box cut out a circular hole large enough to insert the head of a flashlight. Now darken the room and turn on the flashlight (Figure 9–19). The constellation will glow brightly in the "night sky." If the dots of light

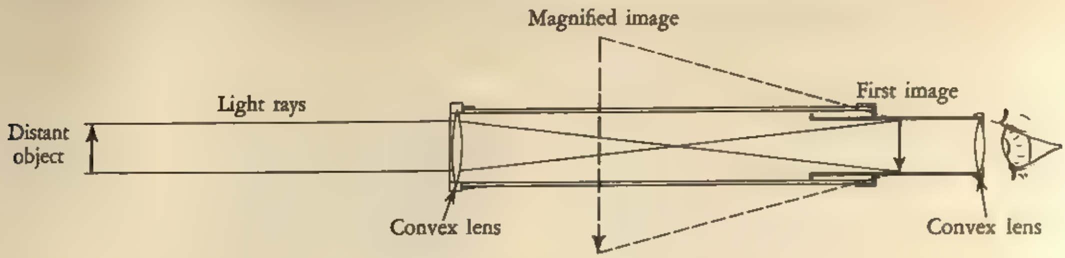


FIGURE 9–20. HOW THE REFRACTING TELESCOPE WORKS.

cannot be seen clearly, make the holes larger with a large sewing needle or a small knitting needle. Replace this constellation with sheets containing other constellation patterns.

6. *The constellations change their position in the sky* · Observe the position of well-known constellations, such as the Big and Little Dippers or Orion, early in the evening and then later in the evening. Their positions will have changed. This apparent change is caused by the earth's rotation. Observe their position 1 night each week for 4 weeks at the same time each night. Again their positions will have changed. This apparent change is caused by the earth's revolution around the sun.

An excellent star chart, called the "Star Explorer," can be obtained inexpensively by writing to Star Explorer, Hayden Planetarium, New York 24, New York. It has excellent instructions and can be adjusted for different times of the year. Use this star chart to locate the constellations in the sky.

7. *Collect pictures of the stars* · Look for and collect pictures of stars, double stars, different varieties of star clusters, nebulae, and galaxies.

8. *The Galaxy* · Locate the Milky Way in the sky, on a clear moonless night as far away from the lights of the city as possible. Binoculars or a small telescope will help. Look for a picture of the Galaxy. Show the position of the sun and the solar system in the Galaxy. Point out the three spiral arms and discuss the differences in the speed of the stars in the Galaxy.

9. *Calculate the distance traveled in a light-year* · The speed of light is about 186,000 miles per second. The distance that light travels in 1 year can be found by multiplying 186,000

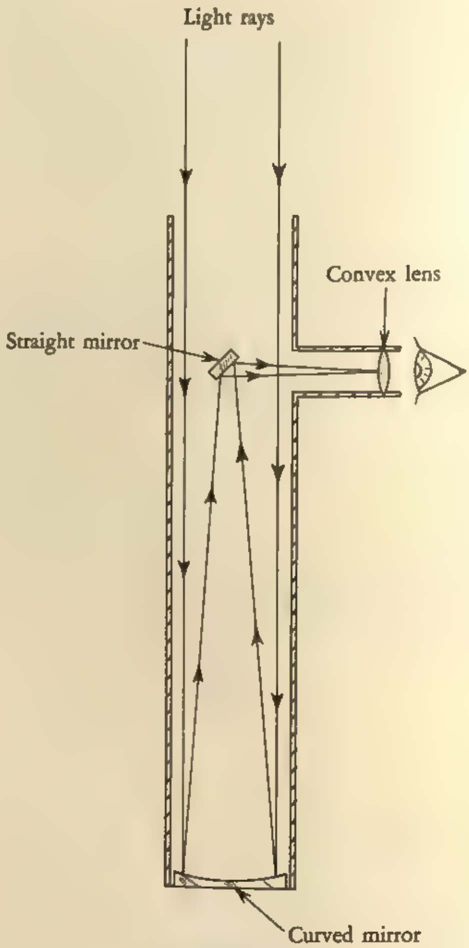


FIGURE 9–21.
HOW THE REFLECTING TELESCOPE WORKS.

by 60 seconds, then by 60 minutes, then by 24 hours, and then by 365¼ days. By multiplying this answer by 3⅓, the distance traveled in a parsec will also be obtained. Point out the parsec is now used instead of the light-year.

10. *The refracting telescope* · Draw a diagram of the refracting telescope (Figure 9–20). Trace the rays of light as they come from a distant object, enter the lens, and are bent to form a small image, which is then magnified by the other lens.

11. *The reflecting telescope* · Draw a diagram of the reflecting telescope (Figure 9–21). Trace the rays of light as they come from a distant object, are collected by the curved mirror, and travel to a straight mirror, where they are reflected and form a small image, which is then magnified by the convex lens.

BIBLIOGRAPHY FOR "THE UNIVERSE"

Andrews, Roy Chapman. *This Amazing Planet.* New York: Putnam, 1940. 231 pp.

Baker, Robert H. *Introducing the Constellations.* New York: Viking, 1957. 209 pp.

———. *When the Stars Come Out* (*rev. ed.*). New York: Viking, 1954. 182 pp.

Blough, Glenn O. *How the Sun Helps Us.* New York: Harper, 1959. 36 pp.

Branley, Franklin M. *A Book of Planets for You.* New York: Crowell, 1961. 65 pp.

———. *Experiments in Sky Watching.* New York: Crowell, 1959. 111 pp.

———. *The Moon Seems to Change.* New York: Crowell, 1960. 36 pp.

———. *The Nine Planets.* New York: Crowell, 1958. 78 pp.

———. *The Sun, Our Nearest Star.* New York: Crowell, 1961. 40 pp.

———. *What Makes Day and Night?* New York: Crowell, 1961. 40 pp.

Fenton, Carroll Lane, and Mildred Adams Fenton. *Worlds in the Sky.* New York: Day, 1950. 96 pp.

Freeman, Mae, and Ira Freeman. *Fun with Astronomy.* New York: Random, 1953. 58 pp.

Gallant, Roy A. *Exploring the Planets.* New York: Doubleday, 1958. 123 pp.

———. *Exploring the Universe.* New York: Doubleday, 1956. 62 pp.

Gamow, George. *The Moon.* New York: Abelard, 1959. 127 pp.

Grey, Vivian. *The First Book of Astronomy.* New York: Watts, 1959. 68 pp.

Hawkins, Gerald S. *Splendor in the Sky.* New York: Harper, 1961. 292 pp.

King, H. C. *Astronomy.* New York: Watts, 1960. 256 pp.

Lauber, Patricia. *All About the Planet Earth.* New York: Random, 1962. 142 pp.

———. *All About the Planets.* New York: Random, 1960. 140 pp.

Lewellen, John. *The True Book of Moon, Sun, and Stars.* Chicago: Childrens, 1954. 46 pp.

LEY, WILLY, and WERNHER VON BRAUN. *The Exploration of Mars.* New York: Viking, 1956. 176 pp.

MALONEY, TERRY. *The Story of the Stars.* New York: Sterling, 1961. 48 pp.

MAYALL, R. NEWTON, and MARGARET MAYALL. *A Beginner's Guide to the Stars.* New York: Putnam, 1960. 184 pp.

MOORE, PATRICK. *The Solar System.* New York: Criterion, 1961. 127 pp.

NEPHEW, WILLIAM, and MICHAEL CHESTER. *Moon Trip.* New York: Putnam, 1958. 63 pp.

PARKER, BERTHA M. *Beyond the Solar System.* New York: Harper, 1959. 36 pp.

———. *The Earth's Nearest Neighbor.* New York: Harper, 1959. 36 pp.

———. *Gravity.* New York: Harper, 1959. 36 pp.

———. *The Sky Above Us.* New York: Harper, 1958. 36 pp.

———. *The Sun and Its Family.* New York: Harper, 1959. 36 pp.

PODENDORF, ILLA. *The True Book of Seasons.* Chicago: Childrens, 1955. 47 pp.

REED, W. MAXWELL. *Patterns in the Sky.* New York: Morrow, 1951. 125 pp.

———. *The Stars for Sam.* New York: Harcourt, 1960. 179 pp.

REY, H. A. *Find the Constellations.* Boston: Houghton, 1954. 72 pp.

SCHLOAT, G. WARREN. *Andy's Wonderful Telescope.* New York: Scribner, 1958. 48 pp.

SCHNEIDER, HERMAN, and NINA SCHNEIDER. *You Among the Stars.* Chicago: Scott, 1951. 55 pp.

TANNENBAUM, BEULAH, and MYRA STILLMAN. *Understanding Time.* New York: McGraw, 1958. 143 pp.

TELLANDER, MARIAN. *Space.* Chicago: Follett, 1961. 32 pp.

WYLER, ROSE, and GERALD AMES. *The Golden Book of Astronomy.* New York: Simon & Schuster, 1955. 97 pp.

ZIM, HERBERT S. *Shooting Stars.* New York: Morrow, 1958. 64 pp.

———. *The Sun.* New York: Morrow, 1953. 64 pp.

———. *The Universe.* New York: Morrow, 1961. 65 pp.

——— and ROBERT H. BAKER. *Stars: A Guide to the Constellations, Sun, Moon, Planets, and Other Features of the Heavens.* New York: Simon & Schuster, 1956. 160 pp.

CHAPTER

The Earth 10

THE COMPOSITION OF THE EARTH

I. How the Earth Was Formed

A. Scientists believe that the earth was formed in the same way as the sun, planets, and other heavenly bodies in the universe were formed.

B. They also believe that the earth must have been formed from the same materials as those that are in the sun.

C. At first the earth was a huge ball of white-hot gases with a temperature of many millions of degrees Fahrenheit.

1. This heat was not produced because of a nuclear reaction that took place inside the earth, as is the case with the sun, but because of the attraction of the particles of gases for each other.
2. As these particles were attracted to each other, they moved closer and closer together until they were pressed together tightly, or compressed.
3. When particles of gases are squeezed together, or compressed, heat is given off.

D. After a long while the earth began to cool.

1. The color of the spinning ball of gas changed slowly from white to yellow to red, until finally the earth gave off no light at all.
2. As the earth cooled, it grew smaller, or contracted, and most of the material changed from a gas to a liquid.
3. The heavier liquid materials settled toward the center of the earth, and the lighter liquid materials floated on top.
4. The lighter liquid materials combined to form molten, or liquid, rock.
5. The rest of the earth's material remained as hot gases above the surface of the liquid.

E. As the earth continued to cool, a solid crust that floated on top of the liquid material was formed.

1. As this crust continued to cool, it contracted, wrinkled, and burst open in many places.
2. More molten rock flowed out through these openings; then it cooled to form solid rock.

F. At this time there was no water on earth.

1. Some water was in the hot gases above the earth in the form of water vapor.
2. Most of the water was trapped beneath the earth's crust.

G. As the earth's crust continued to cool and contract, great cracks appeared, and the trapped water was able to escape into the atmosphere, where it evaporated.

H. When the top of the earth's atmosphere became cool enough, the water vapor condensed into tiny droplets to form thick layers of clouds that covered the earth and shut out the sun.

I. After a while the droplets of water in the

upper layers of clouds combined to form larger droplets, and then some rain began to fall.

1. This rain immediately evaporated into water vapor when it fell into the hot, lower layers of clouds.
2. However, these lower layers of clouds were cooled, after a long time, both by the rain and by the loss of heat energy from the lower cloud layers as they evaporated the rain into water vapor.
3. Eventually the rain reached the earth's surface, but it quickly boiled away when it touched the earth's hot rocks.
4. As more rain fell, it made the earth's crust much cooler, causing the crust to contract and crack even more, so that more of the water trapped inside the earth was squeezed out and evaporated.

J. Finally, the earth's surface became cool enough for water to be able to stay on the earth.

1. The water trickled down the rocks to form small pools.
2. This water was the beginning of the earth's lakes and oceans.

K. For a long time it rained constantly, filling the earth's surface with bodies of water.

L. At this point all of the waters of the earth were fresh, becoming salty only after they had sufficient time to dissolve some of the chemicals in the earth's crust.

M. After thousands of years the thick clouds thinned out as they cooled and gave up their water.

N. At the same time many of the other gases above the earth's surface disappeared.

1. Some of the lighter gases escaped into space.
2. Other gases turned into liquids, and even solids, as they became cooler.

O. The gases that were left behind became our earth's atmosphere.

P. Eventually the sun shone through to the earth, lighting up a bare, bleak earth that only had rocky land masses and bodies of water.

II. The Layers of the Earth

A. The earth is made up of three separate layers: the crust, the mantle, and the core.

B. The crust is a very thin outer layer of rock, which is mostly granite.

1. The raised parts of the rock form the earth's continents and the low parts form the ocean floors.
2. The crust is thickest underneath the continents, and it can be as much as 20 miles thick.
3. The crust is thinnest underneath the oceans, and it can be as little as 7 miles thick.

C. Tremendous forces inside the earth are constantly acting on the crust, causing it to bend and crack, and producing mountains, earthquakes, and volcanoes.

D. In the earth's crust are found the soil, water, coal, oil, gas, and minerals that we use.

E. Although there are at least 90 chemical elements found in the earth's crust, only 5 of these elements make up 90 percent of the crust's weight.

1. Oxygen makes up about 50 percent of the crust's weight, and it is found in air, water, sand, quartz, limestone, clay, and other minerals.
2. Silicon makes up about 26 percent of the crust's weight, and it is found in sand, quartz, clay, and other minerals.
3. Aluminum is the earth's most abundant metal, making up 7 percent of the crust's weight, and it is found in clay and other minerals.
4. Iron makes up about 4 percent of the crust's weight, and it is usually found combined with oxygen and sulfur.
5. Calcium makes up about 3 percent of the crust's weight, and it is found in limestone, bones, and teeth.

F. Beneath the earth's crust is the mantle, or middle layer.

1. There is a sharp boundary or zone, called the Moho, between the crust and the mantle.

2. The mantle goes down to a depth of about 1800 miles.
3. The mantle is made up of rock, called basalt, which is heavier than the granite rock in the earth's crust.
4. Even though the mantle is very hot, the rock in it is solid rather than liquid because of the great pressures exerted on it.
5. Geologists believe that when deep cracks are formed in the earth's crust, the pressure on the mantle is reduced, and the solid rock then turns into liquid rock.

G. Beneath the earth's mantle is the core, or third layer.
1. The core goes down about 2200 miles to the center of the earth.
2. The core is made up of a mixture of about 90 percent iron and 10 percent nickel.

H. The presence of metals in the earth's core seems to confirm the theory of geologists that, as the earth cooled, the heavier materials settled toward the center, and the lighter materials floated up toward the surface.

I. There are two parts to the core: the **outer** and the **inner** core.
1. The outer core is about 800 to 900 miles thick and seems to be in a liquid form.
2. The inner core is about 1300 to 1400 miles thick and seems to be solid.

J. The inside of the earth is very hot.
1. Geologists have found that the temperature rises as they go deeper into the earth's crust.
2. The heat is believed to be formed because the materials inside the earth are squeezed tightly together, or compressed.
3. In mines and oil wells the temperature rises 1 degree Fahrenheit for every 60 feet of depth.
4. Geologists think that the temperature of the mantle may reach as high as 3000 degrees Fahrenheit, and the temperature of the core may be as high as 8000 degrees Fahrenheit.

III. Rocks

A. The solid part of the earth's crust is made up of great masses of hard material called **rock.**
1. The smaller rocks and boulders, with which we are familiar, are just differently sized pieces that were broken off from these large masses.
2. Some large masses may be several miles thick.
3. Most of the rock on the earth's surface is covered with soil.

B. Although there seems to be many different kinds of rocks, they can all be divided into three main groups, according to the way in which they were formed.

C. The three kinds of rocks are—**igneous, sedimentary,** and **metamorphic** rocks.

D. Igneous rocks are rocks formed from molten material deep below the earth's crust.
1. Igneous means "formed from fire."
2. The hot molten material is called **magma.**

E. Magma forms when the pressure below the earth's crust becomes smaller.
1. When the pressure is reduced, the solid material in the earth's mantle becomes liquid magma.
2. The magma may then work its way upward through layers of rock lying above it.
3. The heat and pressure of the flowing magma may also cause the rock above it to move, break up, or even melt, which makes room for the magma to rise.
4. The hot magma may then break through cracks in the earth's surface and flow out, covering wide areas of the land.

F. Rock formed from magma that reached the earth's surface and then cooled is called **extrusive** rock.
1. Liquid magma that reaches the earth's surface is also called **lava.**
2. Extrusive rocks are either glassy or made up of very fine crystals.
3. The magma or lava cools so quickly that

large crystals do not have an opportunity to form.

G. Rocks formed from magma that could not reach the earth's surface because of the rocks lying above the magma, and therefore cooled below the surface, are called intrusive rocks.
   1. Intrusive rocks are coarser than extrusive rocks.
   2. They have larger crystals because the magma cooled slowly.
   3. When the rocks lying above the intrusive rock are worn away, or eroded, the intrusive rock becomes exposed to view on the earth's surface.

H. Granite is the most common igneous intrusive rock.
   1. It is easily recognized by its speckled appearance which is caused by the presence of three minerals—quartz, feldspar, and mica.
   2. Quartz has glasslike crystals that may be colorless or milky.
   3. Feldspar has crystals that may be red, white, gray, or green.
   4. Mica has shiny, flaky crystals that may be black or white.
   5. Granite is used in road construction, buildings, and monuments.

I. Basalt is a common igneous extrusive rock.
   1. It is dark colored, and heavier than granite.
   2. Geologists believe that the continents are resting on a foundation of granite and the oceans on a foundation of basalt.

J. Pumice and obsidian are igneous extrusive rocks formed from magma or lava that has come from erupting volcanoes.
   1. Pumice comes from lava that had many hot gases in it. The lava cooled so quickly that the gases did not have time to escape and they were trapped inside the cooled lava, thus forming a light-colored spongy rock.
   2. Some samples of pumice are so light, because of the many gas bubbles trapped in them, that they can float in water.
   3. Obsidian is another form of lava that cooled very quickly.
   4. Obsidian is black and glassy, and it has the same chemical composition as commercial glass.

K. The second group of rocks, called sedimentary rocks, were formed from layers of sediment that accumulated under water for thousands of years and then were pressed tightly together to form rock.

L. One kind of sediment that forms sedimentary rock includes such materials as sand, clay, mud, pebbles, and gravel.
   1. Streams and rivers carry these sedimentary materials to lakes or oceans, where they slowly settle to the bottom.
   2. As the sediment accumulates, layers are formed, which then slowly change into rock.
   3. This change happens because the weight of the top layers presses the sediment in the bottom layers tightly together.
   4. At the same time, chemicals that are already dissolved in the water now begin to deposit out again on and between the particles of sediment, fill the tiny spaces between the particles, and then cement them firmly together.

M. Conglomerate, sandstone, and shale are examples of sedimentary rock formed this way.
   1. Conglomerate is made of pebbles and gravel that are cemented together.
   2. Sandstone is made of grains of sand that are cemented together.
   3. Some sandstones are sharp and jagged, but others are worn smooth by the action of water and wind on them.
   4. The material that cements the sand together determines the color and hardness of the sandstone.
   5. Sandstone may be red, brown, yellow, or very light colored; it can be very soft or it can be hard enough to use as a building material.
   6. Shale is clay or mud that has become rock mostly by pressure.
   7. Because clay is made of fine, flaky mate-

rials, shale usually can be split easily into flat, thin pieces.

8. The color of shale is usually gray or green, but it may be red, blue, purple, or even black.

N. A second kind of sediment that forms sedimentary rock includes the remains of tiny plants and animals that live in the ocean and take calcium carbonate from the water to form shells or skeletons.

1. As these tiny plants and animals die, their shells and skeletons accumulate to form great beds of calcium carbonate that later harden by pressure into limestone.
2. The limestone formed from corals and other tiny plants that live in clear, warm, shallow water is fine grained and almost pure calcium carbonate.
3. The limestone formed from the remains of the other tiny sea animals, as well as the shells of such larger animals as clams, oysters, and mussels, is much coarser and may have pieces of shell in it.
4. This kind of limestone may also have sand and clay, in small or large amounts, mixed in it.
5. Chalk is a soft porous form of limestone, made from the shells of tiny animals that lived millions of years ago.

O. A third kind of material that forms sedimentary rock includes such chemicals as salt and calcium carbonate, which are dissolved in the seawater.

1. Conditions in the oceans often change so that the water in certain parts of the ocean can no longer hold these chemicals that are dissolved in it.
2. These chemicals then deposit out, forming layers that later harden by pressure into rock.
3. Rock salt is formed from salt that once was dissolved in seawater.
4. A very pure and fine form of limestone is formed from calcium carbonate that deposited out of seawater.

P. Sedimentary rocks often contain the remains of early animals and plants, called fossils, embedded in them.

Q. Iron ores and other metal ores sometimes accumulate as sediment and are then found in sedimentary rock.

R. Soft coal is sedimentary rock formed from the remains of plants that died long ago, accumulated in a slowly sinking swamp, and were covered by other sediment to form layers that were then changed by heat and pressure into a rocky material.

S. The third group of rocks, called metamorphic rocks, are igneous and sedimentary rocks that were buried deeply under other rocks, and then changed by heat and pressure.

1. Metamorphic means "changed in form."
2. Some changes are physical in nature, where the original materials in the rock were only rearranged.
3. Other changes are chemical in nature, where new minerals were formed.

T. Some of the more common metamorphic rocks include gneiss, quartzite, marble, and hard coal.

1. Gneiss is a coarse rock that has parallel streaks or bands of mineral in it, and it is formed from igneous granite.
2. Quartzite is a very hard rock formed from sedimentary limestone.
3. Slate is a fine-grained rock that splits very easily into thin sheets, and it is formed from sedimentary shale.
4. Marble is a fine, large-crystal rock, formed from sedimentary limestone.
5. Hard coal is formed from soft coal, and it has much more carbon in it.
6. Hard coal is also changed by further heat and pressure to graphite, which is pure carbon, now no longer useful as a fuel, but useful for making pencils, as a lubricant, and for other purposes.

IV. Minerals

A. Rocks are made up of one or more minerals.

B. Minerals are chemical elements or com-

pounds that are found naturally in the earth's crust.

C. Minerals are solid materials, having an orderly arrangement of atoms and therefore a definite crystal structure.

D. They are not made, or do not come, from living things.

1. For this reason, a pearl, even though it is a chemical compound, is not considered a mineral, because a living thing—the oyster—produced it.
2. For the same reason coal is not considered a true mineral, because it was formed from plant materials.

E. Most rocks are made up of more than one mineral.

F. Geologists classify minerals into groups, depending upon the kinds of chemicals in them and also upon the structure of the crystals they form.

G. Accordingly, minerals have been classified into four broad groups.

H. The first broad group of minerals includes those that contain the chemical element silicon.

1. The members of this group are called the **silicious** minerals.
2. Well-known examples of this group are quartz, feldspar, mica, olivine, and talc.
3. This group of minerals includes about 25 percent of all the known minerals on earth and about 40 percent of the commonly known minerals.
4. The minerals in granite, which makes up 90 percent of the earth's crust, are found in this group.

I. The second broad group of minerals are those that are considered to be nonmetallic by nature.

1. The members of this group are called the **nonmetallic** minerals, although some of the members contain chemical elements, such as calcium or magnesium, which chemists call metals.
2. Well-known examples of this group are calcite, dolomite, sulfur, rock salt, gypsum, apatite, fluorite, and graphite.

J. The third broad group of minerals are those that contain the common metal ores.

1. The members of this group are called the **metal ore** minerals.
2. Such metals as gold, silver, iron, copper, lead, zinc, tin, aluminum, mercury, titanium, and uranium are found in the minerals of this group.

K. The fourth broad group of minerals are those that are made into precious and semiprecious stones.

1. The members of this group are called the **gem** minerals.
2. Well-known examples of this group are the opal, jade, garnet, topaz, tourmaline, emerald, aquamarine, ruby, amethyst, sapphire, zircon, and diamond.

V. The Identification of Minerals

A. Only rarely can a mineral be identified by applying a single test to it.

B. Geologists usually apply many tests to a mineral before they are absolutely sure they have identified the mineral.

C. Geologists identify minerals by testing the properties, or characteristics, that the minerals have.

D. One test is the **color** of the mineral.

1. Experienced geologists always look at the color of a fresh surface of the mineral.
2. This fresh surface shows the true color of the mineral, rather than the dull or tarnished color of a surface that has been exposed to air or been in contact with particles of soil for a long time.
3. Sometimes amateur geologists are confused by small amounts of impurities in the minerals, which change the true color of the minerals.

E. Another color test is the **streak** test.

1. The streak is the color produced when the mineral is rubbed against a piece of unglazed porcelain tile, which is called a **streak plate**.
2. Nonmetallic minerals will produce a col-

orless or very light-colored streak, but metallic minerals often produce a dark streak that may differ from the original color of the mineral.

F. Still another color test is the **luster** of the mineral.
   1. Luster is the shine that the mineral has when light strikes it.
   2. Such terms as dull, pearly, silky, metallic, glassy, and brilliant or diamondlike are used to describe the luster of a mineral.

G. Another way to identify minerals is by observing the **crystal form** of the mineral.
   1. Most minerals are made up of crystals, showing that the atoms in the minerals are arranged in definite patterns.
   2. These crystals have distinct forms, such as a square, double triangle, pyramid, or cube.

H. Geologists also identify some minerals by the way they split or break when struck.

I. A very widely used test for minerals is the hardness test.
   1. Minerals differ very much in hardness; consequently, if the hardness of a mineral is known, it is a great help in identifying it.
   2. Because there is so much difference in hardness, certain minerals are used as standards of hardness, and all the other minerals are compared with these special minerals.
   3. These standard minerals are arranged in a scale, in which the minerals are listed in the order of their hardness, with the softest mineral listed first.

J. The commonly used scale of hardness is called **Mohs' scale**.
   1. Mohs' scale has ten minerals in it, arranged in the order of their hardness, with each mineral being harder than the ones above it in the scale.
   2. Talc, which is one of the softest minerals, is first in the scale, and the diamond, which is the hardest of all minerals, is last in the scale.

K. Ten minerals make up Mohs' scale, as follows.

1. Talc.	6. Orthoclase.
2. Gypsum.	7. Quartz.
3. Calcite.	8. Topaz.
4. Fluorite.	9. Corundum.
5. Apatite.	10. Diamond.

L. The hardness of a mineral is found by using it to make scratches on the minerals in Mohs' scale.
   1. The geologist finds out which minerals in the scale the unknown mineral can and cannot scratch, and then the geologist determines the hardness of the mineral.
   2. For example, apatite, 5, is harder than fluorite, 4, but softer than orthoclase, 6.
   3. Any mineral that scratches apatite, but not orthoclase, is said to have a hardness on Mohs' scale of between 5 and 6.
   4. This mineral will also scratch all the minerals below apatite and will scratch none of the minerals above orthoclase in the scale.

M. The following simple materials also help determine the hardness of a mineral on Mohs' scale.
   1. A fingernail has a hardness of about 2.5, and it will scratch gypsum, 2, but not calcite, 3.
   2. A penny has a hardness of 3, and it will just about scratch calcite, 3, but not fluorite, 4.
   3. The sharp point of a piece of glass or the blade of a jackknife has a hardness of 5.5; it will scratch apatite, 5, but not orthoclase, 6.
   4. A steel (tool) file has a hardness of 6.5.

N. Another way to identify minerals is to find the specific gravity, or heaviness, of the mineral.

O. Geologists also use special tests for certain groups of minerals.
   1. Some minerals, such as lodestone or magnetite, are magnetic and will be attracted by a magnet.
   2. Some minerals, such as sulfur, will be-

come electrically charged when rubbed or squeezed.

3. Some minerals, when exposed to invisible ultraviolet light, become fluorescent and give off light.
4. Many of these fluorescent minerals are also phosphorescent, and they will give off light after the ultraviolet light has been turned off.
5. Some minerals, such as uranium, are radioactive.
6. When a drop of dilute hydrochloric acid is placed on a mineral containing calcium carbonate, a chemical reaction takes place and bubbles of carbon dioxide gas are given off.
7. Some minerals give a special color to a flame when a bit of the powdered mineral, which has first been moistened with hydrochloric acid, is placed on one end of a clean platinum wire and thrust into the flame.
8. Certain minerals will give a special color to powdered borax that has been put on one end of a clean platinum wire and heated to form a small glassy bead; the color changes when some of the powdered mineral is put on the bead and the bead is thrust into a flame that has been made hotter with a blowpipe.

VI. Conservation of Our Minerals

A. Economists classify our mineral resources into three main groups: **metals, nonmetals,** and **fuels.**

1. Metals include such materials as iron, aluminum, lead, zinc, copper, and silver.
2. Nonmetals include such materials as limestone, marble, quartz, slate, and phosphates.
3. Fuels include such materials as coal, petroleum, and natural gas.

B. Our mineral resources are sometimes called **fixed resources,** or nonrenewable resources.

1. Our plant and animal life can be used over again many times, or replaced, so that with careful management they can last indefinitely.
2. But most minerals, after they have been taken from the ground, are gone forever.

C. Because minerals cannot be replaced and because we use more minerals each year, the problem of conserving our mineral resources is important.

1. We must use our metals wisely and efficiently.
2. We must find ways to extract metals from low-grade ores.
3. We must locate and develop fresh sources of minerals.
4. We must develop substitutes for minerals that are being used up quickly.

D. Although we use a large amount of coal each year, there is still enough coal available to last for several generations.

E. However, our petroleum and natural gas supplies are being used so quickly that we shall soon face the problem of having to do without them.

F. Scientists are constantly looking for ways to extend our fuel supplies.

1. They have developed improved methods of mining coal and using low-grade sources.
2. They are developing better techniques of drilling and pumping petroleum so that we get more petroleum from each oil well.
3. They have improved the methods of refining petroleum to give us more gasoline and Diesel oil.
4. They are experimenting to find an inexpensive way of preparing gasoline from natural gas and from coal.

G. We can do much to help scientists and fuel experts in conserving fuel.

1. Insulation of homes will cut the use of fuel.
2. Many home owners waste fuel by keeping the temperature too high inside during the winter.
3. Many automobile engines waste gasoline because their carburetors are not adjusted properly.

FORCES THAT SHAPE AND CHANGE THE EARTH'S SURFACE

I. The Solid Parts of the Earth Can Move

A. Geologists have discovered that the solid parts of the earth can move and have moved, both a long time ago and fairly recently.

B. In some cases, parts of the earth's crust have been lifted.
1. Islands have risen from the deep Pacific Ocean.
2. Parts of continents, as in Sweden and Finland, have been raised.
3. Long ago the basins of the Great Lakes were tilted and lifted to a higher position than they were originally.

C. In some cases, parts of the earth's crust have sunk.
1. Occasionally, islands in the Pacific Ocean have disappeared beneath the water.
2. Parts of continents have been lowered, allowing shallow seas to cover them.

D. Sometimes there has been horizontal motion of the earth's crust, where large layers of rock move in wavelike folds, or slide over one another, and take up new positions.

E. Geologists are not sure why these movements of the earth take place, but there are four theories that are common today, which try to explain this movement.

F. According to the **theory of isostasy** (which means "equal standing"), the continents, ocean basins, mountains, and plains are all in a state of balance.
1. These land forms keep this balance by slowly adjusting their positions.
2. As rock from a higher region is worn down and carried away to a lower region, the higher region becomes lighter and rises slowly while the lower region becomes heavier and slowly sinks.
3. This theory helps explain why the wearing down of mountains and the filling up of ocean basins have not produced a level surface all over the earth.
4. The theory also explains why thick beds of sediment can be found in ocean basins without filling up the oceans.
5. However, the theory does not explain why the rock layers in the earth's crust will move in wavelike folds to form mountains, or move horizontally over each other to form earthquakes.

G. According to the **contraction theory** the earth is gradually shrinking, either because it is cooling or because great pressures are squeezing parts of it into a smaller volume.
1. Because of this shrinking, the inside of the earth is always becoming a little too small for the outside crust.
2. To adjust this condition, the stronger and heavier parts of the crust sink, crowding and squeezing the lighter parts, which are then pushed upward.
3. This theory does explain why the layers of rock in the earth's crust move to form mountains and earthquakes.

H. According to the **convection theory**, a convection current takes place inside the earth, where the warmer, lighter parts of the earth rise while the colder, heavier parts fall.
1. Convection currents take place only with liquids and with gases, but not with solids.
2. However, although the rock inside the earth is solid, the rock is very hot and under great pressure, and with such conditions the rock will move just as if it were liquid.

I. According to the **continental drift theory**, there was only one large continent when the earth cooled.
1. This single continent was made up mostly of granite, which, being lighter

than the rocks beneath it, floated on top of these rocks.

2. Over a period of time the continent broke up and the different parts drifted away.
3. When the different parts came to rest, they pushed hard against the ocean basins, and the mountain ranges were formed.

II. Folding and Faulting

A. Because of great temperature and pressure, tremendous sideward forces will often act on horizontal layers of rock—especially sedimentary rock layers—making them bend and wrinkle, and pushing them into wavelike **folds.**

1. These wavelike folds of rock have a crest and a trough, just like ocean waves.
2. The crest of a rock fold is called an **anticline**, and the trough is called a **syncline.**

B. Some rock folds may be very small, but others are so large that they produce great mountain ranges.

C. Sometimes, in the process of folding, the rock may crack or break rather than bend.

D. Under great pressure, layers of rock may slide over one another along this crack or break.

E. The crack or break in the rock where this movement takes place is called a **fault** and the movement of the rock itself is called a **faulting.**

F. Both folding and faulting play an important part in shaping and changing the earth's surface.

III. Earthquakes

A. Most **earthquakes** happen when faulting takes place.

1. The layers of rock that lie next to a crack, or fault, are pressed very tightly together.
2. These layers are under very great strain because one layer is usually being pushed in one direction while the other layer is being pushed in the opposite direction.
3. After many years of slowly increasing pressures, there is a sudden movement as the layers of rock slide over one another and come to rest in a new position that eases the pressure.
4. As the rock layers grind against each other when this sudden movement takes place, they set up violent vibrations that can shake large land masses for many minutes.
5. These layers of rock may slip only an inch or so, but the slippage may set up earthquake vibrations that can destroy a whole city.

B. Sometimes the earthquakes and their vibrations take place just below the surface, and sometimes they take place deep inside the earth.

C. Although earthquakes may take place all over the earth, they happen most often along two large areas of the earth, called **earthquake belts.**

1. These earthquake belts are usually areas where high mountain ranges are next to deep ocean floors.
2. It seems as if these areas are weak parts of the earth's crust.
3. One earthquake belt circles the Pacific Ocean, starting with Chile and going northward to Peru, Central America, Mexico, California, and Puget Sound, then to the Aleutian Islands and Japan, and southward to the Philippines, Indonesia, and New Zealand.
4. The second earthquake belt includes the mountainous areas next to the Mediterranean Sea, a section of Northern Africa, and Asia Minor and southern Asia.

D. Earthquakes that begin under the ocean set up huge sea waves, called **tsunamis.**

1. Tsunamis are mistakenly called "tidal waves."
2. Tsunamis may travel as fast as 500 miles an hour and may be more than 100 feet high when they reach the seacoast.

E. Earthquakes are detected by an instrument called a **seismograph.**
   1. When an earthquake occurs, the vibrations that are produced will travel as waves through the earth.
   2. The seismograph detects and records these vibrations and tells us where the earthquake took place and how strong the vibrations are.

IV. Mountains

A. **Mountains** are great masses of rock pushed high into the air by forces inside the earth.
B. All true mountains are made up of rock masses that are in a nonhorizontal position.
C. Mountains are formed in four different ways, in which the masses of rock have been folded, tilted, shaped into domes, or built up from volcanic materials.
D. **Folded** mountains are formed when layers of sedimentary rock are pushed into wavelike folds by tremendous sideward forces produced by great heat and pressure within the earth.
   1. The **anticlines,** or crests of these waves, become mountains.
   2. The **synclines,** or troughs of these waves, become valleys.
   3. Folded rocks can be uplifted many times over a long period of time, producing a whole region of long ridges that curve back and forth on each other.
   4. The Appalachian Mountains are examples of folded mountains.
E. **Block** mountains are formed when folded layers of sedimentary rock break or crack, producing a fault.
   1. Eventually faulting takes place, and the layers of rock on one side are pushed up higher than the layers of rock on the other side.
   2. The layers of rock often tilt to one side after they have been pushed up.
   3. Mountains formed in this way are called block mountains because they look like huge blocks.
   4. In some areas block mountains are called "hogbacks" because one side of the mountain is steep and almost vertical, and the other side has a gentle slope.
   5. The Sierra Nevadas are an example of block mountains.
F. **Domed** mountains are formed when molten rock, or magma, inside the earth flows up and between two layers of rock.
   1. As the molten rock accumulates, it pushes up the layers of rock above it to form a large dome.
   2. The Black Hills of South Dakota and the Adirondack Mountains of New York are examples of domed mountains.
G. **Volcanic** mountains are formed by the building up of lava and other materials that are thrown up when a volcano erupts.
   1. These mountains build up gradually as they accumulate the materials from erupting volcanoes.
   2. Mount Lassen and Mount Rainier in the United States, Mount Popocatopetl in Mexico, Mount Vesuvius in Italy, and Mount Fujiyama in Japan are all examples of volcanic mountains.
   3. Volcanic activity, going on in the ocean floor near the Aleutian Islands and the Hawaiian Islands, is building up a series of volcanic mountains at the bottom of the ocean around both of these areas.
H. Mountains are usually grouped together to form a **mountain range,** with a series of peaks of different heights strung in a line.
I. Many ranges that are side by side, or parallel, are called a **chain** of mountains.
J. The Rocky Mountains are really a chain of many parallel mountain ranges.
K. Mountains go through a life history, in which they pass from youth to maturity to old age.
L. During their youth the mountains are still growing.
   1. Young mountains are high and rugged, with steep slopes, rushing streams, and narrow valleys.
   2. Many young mountains have snow all

the time on their tops, and snowslides and avalanches are quite common.

3. The Rocky Mountains, Andes Mountains, Alps, and Himalaya Mountains are examples of young mountains.

M. At maturity the mountains have stopped growing.

1. The action of water, ice, wind, and other elements of the weather wears away the mountains, lowering their peaks and making the slopes more gentle.
2. Sometimes the mountains become so much lower that trees grow to the very top of the mountains.
3. The streams flow more slowly and the valleys become much wider.
4. The Appalachian Mountains, the Adirondack Mountains, and the White Mountains are examples of mature mountains.

N. At old age the mountains have been worn down until they are almost level.

1. The flat surface that is left is called a peneplane, which means "almost a plane level."
2. Southern New England and the areas of Manhattan and Westchester County of New York are peneplanes.
3. Sometimes a peneplane has low, rolling hills with an occasional high hill, called a monadnock, which is made of hard igneous rock that resisted wearing away and so remained behind.
4. Monadnock Mountain in New Hampshire and Pikes Peak in Colorado are examples of monadnocks.
5. The rivers of old mountain areas move very slowly and have low banks.

O. After mountains have passed through their life history and have been worn away, the process of mountain building eventually starts again.

V. Plains and Plateaus

A. Plains and plateaus are different from mountains because they are made up of sedimentary rock layers that are in the same horizontal position in which the layers were originally formed.

B. **Plains** are flat surfaces of land at a low level, and **plateaus** are flat surfaces of land at a high level.

C. **Coastal** plains are made up of pieces of rock that either were worn away from rocks along the seashore by ocean waves or were carried by rivers to the ocean.

1. The wave motion of the ocean spread out the pieces of rock until a smooth, flat surface was formed.
2. A coastal plain extends into the ocean, sometimes for hundreds of miles, forming what is called the continental shelf.
3. Sometimes forces inside the earth lift up all or part of the continental shelf so that it too becomes a coastal plain.
4. Some coastal plains are very narrow, and others are quite broad.

D. **Interior** plains were formed from large, shallow inland seas.

1. Sediments filled up these shallow seas until the water disappeared and flat plains were formed.
2. The Great Plains of the United States and the Argentine pampas are examples of interior marine plains.

E. **Lake** plains were formed from the bottom of large lakes.

1. Some lake plains were formed when forces inside the earth's surface caused the lake floor to be lifted.
2. Other lake plains were formed when conditions caused all the water in the lakes to drain away.
3. The largest lake plain in North America includes a large part of Minnesota, North Dakota, and the provinces of Saskatchewan and Manitoba in Canada.

F. Most plateaus were formed by forces inside the earth's surface that raised horizontal layers of sedimentary rock straight up, high into the air.

G. Some plateaus were also formed by lava flowing out of cracks in the earth, spreading out over a large area and forming a level region of layers of volcanic rock.

H. Plateaus, like mountains, also have a life history, passing from youth to maturity to old age.

I. Young plateaus are very high and flat, and they have not been worn away much by rivers flowing through them.

J. Mature plateaus are often called mountains, even though they are not true mountains.

1. They are mistakenly called mountains because many rivers and streams have cut wide valleys through the broad surfaces of the original plateau, giving the effect of a series of mountains.
2. The tops of these "mountains" are usually flat.
3. The Catskill Mountains are an example of a mature plateau.

K. At old age, plateaus are worn almost level, with only a few parts of the original plateau standing here and there.

1. In dry areas the parts that remain have high walls and flat tops.
2. The large plateaus with broad tops are called mesas, and the smaller plateaus with more rounded tops are called buttes.
3. Both mesas and buttes are found in New Mexico and Arizona, but mostly buttes are found in North Dakota, South Dakota, Montana, and Wyoming.
4. In humid areas the remaining parts of a plateau are more rounded, and they look more like hills.

VI. Volcanoes

A. A volcano is a mountain or a hill formed around a crack in the earth's crust, through which molten rock and other hot materials are thrown out.

1. The rock inside the earth's mantle is very hot, but it is solid because of the great pressures upon it.
2. When the pressure upon some of this solid rock is reduced, such as when a crack or fault forms in the earth's crust, the rock becomes a liquid, called magma.
3. The molten rock, or magma, flows upward and reaches the earth's surface, either through the crack that was formed or through a weak spot in the earth's crust.

B. A volcano gives off steam and chemicals in gaseous form.

1. Many of these gases are poisonous.
2. Also, the gases are so hot that they can either burn the entire body or burn the lungs when inhaled.

C. A volcano also throws pieces of rock high into the air.

1. Some pieces are very large, weighing many tons.
2. Other pieces are the size of cinders or dust.

D. When molten rock, or magma, reaches the earth's surface it is called lava.

1. Sometimes the lava hardens to form a smooth surface, and other times it hardens to produce a ropelike or billowy appearance.
2. If the lava cools slowly, the solid lava will have large crystals in it.
3. If the lava cools quickly, it will have many tiny crystals in it or it will have no crystals at all, whereupon it appears glassy.
4. Pumice is lava that is very spongy and light because it cooled so quickly that the hot gases inside it did not have time to escape and were trapped inside the lava.

E. Volcanoes erupt in different ways.

F. Quiet volcanoes, such as Mauna Loa in Hawaii, do not explode, but send fountains of lava hundreds of feet into the air.

1. The lava is very hot and liquid, and it gives off its gases quite readily.
2. This lava spreads out quickly to form a broad cone with gentle slopes.

G. Explosive volcanoes, like Kileauea in Hawaii, explode with tremendous violence.

1. Very often loud rumblings and earth-

quakes take place first, making cracks and producing hot springs.
2. These volcanoes explode because the magma and hot gases have been held back under tremendous pressure, which is released suddenly.
3. Volcanoes of this type form very narrow, steep cones.

H. Intermediate volcanoes, like Stromboli in the Mediterranean Sea near Sicily, alternate between being quiet and explosive.

I. The opening at the top of the volcano is called the **crater.**
1. Usually the crater is rather narrow, but sometimes the upper part of the crater will blow apart or collapse, forming a very wide basinlike hollow called a **caldera.**
2. These calderas often fill with water and become a lake, such as Crater Lake in Oregon.

J. Volcanoes are usually classified as **active, dormant,** or **extinct.**
1. Active volcanoes are those that are erupting or have recently erupted.
2. Dormant volcanoes are those that have not erupted for some time, but still show signs of some activity.
3. Extinct volcanoes are those that have not erupted for a long time, with no signs of activity.

K. Almost all of the volcanoes on earth are found in the same place as the two earthquake belts.
1. One belt circles the Pacific Ocean, and the other belt extends from the Mediterranean area eastward across Asia Minor and the southern part of Asia.
2. There are also volcanic areas in Iceland, the Azores, and some islands in the West Indies.

L. In the area around the Aleutian Islands and the Hawaiian Islands large volcanic mountain chains are being built up at the bottom of the ocean.

M. Most of the islands in the South Pacific are really the tops of submerged extinct volcanoes.

VII. Hot Springs and Geysers

A. Hot springs and geysers are common where volcanic activity is going on below the surface of the earth.

B. **Hot springs** are formed when underground water is heated by hot rock or gases below the earth's surface and then flows to the surface before cooling off.
1. The passageway along which the water travels is fairly straight so that the water reaches the surface quickly and easily.
2. The temperature of the water may range from just warm to boiling.
3. On its way to the surface the water dissolves large amounts of minerals.
4. These minerals are deposited around the mouth of the hot spring when the water evaporates, and they tend to build up colored layers or terraces.

C. A geyser is a hot spring that throws its water high into the air from time to time.
1. This eruption of water occurs because the geyser has to travel up a narrow, twisted passageway to reach the earth's surface.
2. Heated water is often trapped in this passageway, where it continues to be heated far above its boiling point of 212 degrees Fahrenheit without being changed into steam.
3. This superheating of the water is possible because of the weight of the water on top pressing down on the water below.
4. Eventually some of the water on top does boil and is spilled out.
5. This loss of water on top eases the pressure on the superheated water on the bottom so that some of it is suddenly changed to steam, which blows all the water above it up to the earth's surface and high into the air.
6. After the geyser erupts, some of the water flows back into the passageway, where it meets more underground water coming up, and the process starts again.
7. Some geysers, like Old Faithful in Yel-

lowstone National Park, erupt at regular intervals; others erupt at very irregular intervals.

8. Almost all the geysers in the world are found in only three places: Yellowstone National Park, Iceland, and New Zealand.

FORCES THAT WEAR AWAY THE EARTH'S SURFACE

I. The Earth's Surface Is Always Changing

A. Although the surface of the earth appears to be quite solid and permanent, it is always changing.

B. The rocks that make up the earth's surface are always being broken up and carried away.

C. The process of breaking the rocks into small pieces is called **weathering.**

1. Weathering is caused by the action of the sun, air, and water.
2. There are two kinds of weathering: **mechanical or physical weathering,** and **chemical weathering.**

D. The process of taking away the products of weathering is called **erosion,** and it is carried on by water, ice, and wind.

E. The forces of weathering and erosion are constantly at work on the earth's surfaces, but forces inside the earth keep building these surfaces up again.

II. Mechanical or Physical Weathering

A. Mechanical weathering is the breaking down of rock into small pieces without any chemical changes in the rock itself.

B. One way that mechanical weathering takes place is water seeping into cracks and pores of rocks and then freezing.

1. When water freezes it expands and exerts much pressure, which causes pieces of rock to break off.
2. This kind of weathering takes place when the days are above freezing and the nights are below freezing.

C. Another way that mechanical weathering takes place is rock being heated by day and cooled by night, with the temperature above freezing in both cases.

1. This kind of weathering happens more often in humid places.
2. When rocks are heated during the day, the minerals in them expand.
3. Water that seeps into the rocks combines with these minerals, causing them to swell and form cracks in the rocks.
4. At night the rocks cool and contract, causing the outside of the rocks to peel off in thin layers or sheets.
5. This process, where layers are peeled off rock, is called **exfoliation.**

D. Plants can cause mechanical weathering because, as shrubs and trees grow, their roots work into small cracks in the rock, making the rock split and crumble.

E. Animals also play a part in mechanical weathering.

1. Burrowing animals, like gophers and prairie dogs, dig constantly and expose new rock surfaces for weathering.
2. Earthworms bring fine particles of rock to the surface, and they also make tiny passageways in the earth, which let air and water enter the soil easily.

F. A wind which carries fine rock particles can rub away solid rock.

III. Chemical Weathering

A. In chemical weathering chemical changes take place in the rock, forming new products that can be carried away more easily than the original rock.

B. Chemical weathering is more likely to take place in areas where the air is humid or where water is present.

C. The carbon dioxide gas in the air can produce chemical weathering in certain rocks.
   1. When carbon dioxide from the air dissolves in water, it forms a weak acid called **carbonic acid.**
   2. Carbonic acid attacks minerals like limestone, forming materials that dissolve easily in water and are carried away.
   3. Most rocks have at least one mineral that is affected by carbonic acid, and, when this mineral is removed, the rest of the minerals are exposed, making it easier for other forms of weathering to break them up.

D. The oxygen in the air combines directly with many minerals in rocks, forming materials that crumble easily.

E. Water, either in the air or on the ground, combines with many minerals, causing them to swell and form cracks in the rock, making it easier for mechanical weathering to take place.

F. Small plants, called **lichens,** grow on rocks and produce chemical weathering.
   1. The lichens use the minerals from the rock to live and grow.
   2. The lichens obtain these minerals by giving off an acid that attacks the rock and breaks it up.

G. When plants and animals die and decay, acids that attack the rock and make it crumble are formed.

IV. Erosion by Water

A. Water is the greatest of all the forces that produce erosion.
   1. Each year about 9000 cubic miles of water fall on the earth's land surface.
   2. Some of this water seeps into the earth and stays there as groundwater.
   3. Some water evaporates back into the air.
   4. The rest of the water flows over the earth's surface in a huge number of streams and rivers.
   5. This running water carries with it the materials formed by weathering, and it carries them to lakes and oceans, where they are deposited.

B. Groundwater causes erosion below the earth's surface.
   1. The carbon dioxide in the air combines with water to form weak carbonic acid, which attacks limestone and forms materials that dissolve in water and are carried away.
   2. Where much limestone is present, large caves are formed because of the action of carbonic acid upon the limestone.
   3. Sometimes the underground water, which has limestone dissolved in it, will form solid deposits inside these caves.
   4. The underground water forms these deposits by dripping so slowly through the roof of these caves that some of the water evaporates, and the limestone in the water deposits out again.
   5. Over a long time limestone "icicles," called **stalactites,** will hang from the ceiling of the caves, and columns of limestone, called **stalagmites,** will form on the floor.
   6. The Carlsbad Caverns in New Mexico and Mammoth Cave in Kentucky are examples of caves with stalactites and stalagmites in them.

C. Running water causes erosion on the earth's surface.
   1. As rainwater runs off to join streams and rivers, it carries particles of soil and rock with it.
   2. As the water flows in the streams and rivers, it wears away the beds and causes the sides to cave, making the streams and rivers wider.
   3. The particles of rock in the water also act as weathering forces to wear away more of the earth's rock.
   4. The running water in streams and rivers continues to carry these pieces of rock with it to oceans and lakes.
   5. Many large rivers move very slowly as they near the mouth of an ocean or lake,

and they then drop the materials they are carrying, forming land deposits called **deltas.**

D. The oceans both erode and build up the earth's surface.
   1. The waves, pounding against the rocks and land along the shore, wear them away and then carry off the rock particles.
   2. At Cape Cod 2 to 6 feet of shoreline are worn away by the ocean each year.
   3. The waves will also carry materials, such as sand and pebbles, to the shore and make sandy beaches.
   4. However, storms and strong undertows will often carry beach materials away faster than the waves can deposit them.
   5. Some waves will deposit materials just off the shore, forming sandbars and sandy islands.

V. Erosion by Ice

A. **Glaciers** are huge masses of ice formed where the climate and weather are very cold.
   1. In these places much snow falls each year, and more snow falls than can melt or evaporate.
   2. The snow stays from one year to the next, accumulating layers that pile up into deep masses.
   3. The great weight of the snow presses on the layers underneath, causing these layers of snow to melt and refreeze again as ice grains or pellets, called **neve.**
   4. In the lowest layers the pressure is so great that the neve is recrystallized again to form one solid mass of ice.
   5. Each winter more layers are added to the top, forming more ice below.
   6. Eventually the weight of this huge mass of snow and ice becomes so great that the whole mass begins to move slowly.
   7. This moving mass of ice is called a **glacier.**

B. **Valley** glaciers are glaciers formed in mountain valleys where snow remains the whole year.
   1. Some valley glaciers are quite small, but, others are very large.
   2. As the valley glacier begins to move to lower levels, it gouges out the rock beneath it and carries the broken pieces with it.
   3. As the valley glacier moves, it also picks up more rock that it has worn away from the sides of the valley.
   4. These rocks, embedded in the ice, act as a huge file to wear away the earth over which the glacier passes.
   5. This movement of the valley glacier tends to smooth out the valley floor.
   6. At the same time, the glacier grinds away the valley walls and straightens sharp bends, changing the V-shape of the valley to a broader U-shape.
   7. As the valley glacier moves, it often forms large cracks, called **crevasses,** at the top and sides of the glacier.
   8. When the glacier meets warmer temperatures, the lower end melts and drops the material that it has been carrying.
   9. The material that has been dropped is called a **moraine.**

C. **Continental** glaciers are found only at the polar regions today.
   1. In the polar regions the average temperature is below freezing, and most of the snow that falls stays from one year to the next.
   2. As a result, a glacier is formed that covers a tremendous amount of land surface, which is why it is called a continental glacier.
   3. The continental glacier at the North Pole, which covers almost all of Greenland, is more than 650,000 square miles in area and more than 8000 feet thick.
   4. The glacier that covers Antarctica at the South Pole is more than 5 million square miles in area and more than 14,000 feet thick.
   5. These continental glaciers, covering

Greenland and Antarctica, move outward toward the seacoast.

6. The rise and fall of the tides snap off large pieces of the glaciers, which then float away as icebergs.
7. Because of their huge size and weight, continental glaciers tend to smooth the surfaces over which they pass by grinding down the higher parts of the land and filling in the valleys.
8. Where parts of the earth's surface are softer than other parts, the glacier may often gouge out huge depressions or basins.
9. When the climate becomes warmer and the glacier retreats, these basins often remain, fill with melted ice from the glaciers, and become lakes.

D. The earth has gone through glacial periods in which large parts of the earth were covered by glaciers.

1. All of these glacial periods followed a regular cycle.
2. First the climate became much colder, and huge glaciers formed at the poles.
3. These glaciers moved from the poles toward the equator and covered large parts of the earth.
4. Then the climate became warmer, whereupon the glaciers melted and retreated back to the poles.
5. The retreating glaciers left behind both the rocky materials, or moraines, they brought with them and the grinding changes they made on the earth's surface.

E. The earth has had four of these glacial periods.

1. The first period occurred about 800 million years ago, and it was followed by a warm period of roughly 3 million years.
2. The second period came about 500 million years ago, and it was again followed by a warm period of about 300 million years.
3. The third period came about 200 million years ago, and the fourth period about 100 million years ago.
4. At present we seem to be in a warm period, where the glaciers are retreating.

VI. Erosion by Wind

A. The chief work of wind is to carry away loose bits of soil and rock.

1. This erosion is quite common in dry areas where there are few plants, shrubs, or trees to cover the ground and protect it.
2. Even mild winds constantly move fine particles of dust and rock, but strong winds can create tremendous dust storms.
3. Over a long time, wind can blow away all the loose material from a desert floor, leaving only a floor of bare rock behind.

B. The wind can also deposit materials, especially when it slows down.

C. The most common wind deposits are hills of sand, called **dunes.**

1. Dunes are formed when something is in the way of the wind, slowing the wind down and causing it to deposit the particles it has been carrying.
2. As the mound of deposited material grows, it helps to slow down the wind even more, so that more material is deposited.
3. In this way the dune grows until it is many feet high.
4. Winds will often move sand dunes from one place to another unless grass or shrubs are planted, which cover the sand sufficiently to hold it in place.
5. Sometimes fences are put into dunes to prevent the dunes from moving and covering highways, railroads, or even buildings.

D. Another kind of wind deposit is a fine sediment called **loess.**

1. This material is sometimes deposited over large areas of land, and the deposits are quite thick.
2. If water is available, loess makes very fertile soil.

E. The wind also serves as a weathering agent as well as an erosion agent.

1. As the wind blows against solid rock, the particles of rock that the wind is carrying often rub against solid rock and wear it away.
2. The pebbles in beaches are often made smooth this way.
3. Rocks and boulders in deserts are also made smooth this way.

SOIL

I. How Soil Is Formed

A. Although the forces of mechanical and chemical weathering act on rock very slowly, over millions of years these forces have broken up almost all the rock on or near the earth's surface.
   1. This is the reason why the earth's surface has a layer of pieces of rock on it.
   2. These pieces of rock are all sizes, ranging from tiny pieces to large boulders.
   3. This layer of pieces of rock is called **mantle rock.**

B. The forces of weathering continue to act on this mantle rock until a layer of **soil** is formed.
   1. Soil is made up of tiny grains of rock and minerals.
   2. Soil that has not moved from the original mantle rock that formed it is called **residual soil.**
   3. Soil that is carried by erosion from one place to another is called **transported** soil.

C. Soil becomes fertile when **humus,** the remains of dead animals and plants, is added to it.

D. Because humus is added only to the top portion of the layer of soil, there is a difference in the quality of the soil layer.

E. The first eight inches of soil is called the **topsoil.**
   1. This layer of topsoil is rich in humus.
   2. The topsoil also has air spaces in it, which are filled with either air or water.
   3. The topsoil is fertile, and it is the soil that makes crops grow.
   4. Geologists estimate that about one inch of topsoil is formed in about 500 years.

F. The soil underneath the topsoil is called the **subsoil.**
   1. The subsoil is a much thicker layer than the topsoil.
   2. It has little or no humus in it.
   3. It also has a lot of pebbles in it.

G. Beneath the subsoil is the solid bedrock from which soil was originally made.

II. Kinds of Soil

A. Soil contains different sizes and kinds of rocks and minerals.
   1. These different rocks and minerals usually include large pebbles or gravel, smaller particles of sand, and tiny particles of clay.
   2. Soil may also contain particles of silt, which is smaller than sand but larger than clay.

B. Soil is classified according to the predominant kind of material within it.

C. **Sandy** soil has mostly sand in it, together with a little clay, and it contains almost no humus.
   1. Sandy soil does not hold water very well, and the water drains off quickly.
   2. There are very few minerals in sandy soil that plants can use.

D. **Clay** soil has mostly clay in it, together with a little sand and humus.
   1. Clay soil holds water very well, and it dries very slowly.
   2. However, clay soil is sticky when wet, and it becomes almost as hard as rock when dry.

E. **Loam** is soil that has proper amounts of

gravel, sand, and clay in it, together with lots of humus.

1. It is usually dark brown, or even black, in color.
2. Loam is the best soil for most crops.

F. The best way to use soil for growing crops is to cultivate it.

1. When soil is cultivated, the large clumps are broken up and the earth around the plant roots is loosened.
2. This loosening makes it easier for plant roots to go down into the soil, and it also lets air and water get to the roots.
3. Cultivation of the soil is done by a spade, hoe, rake, plow, and harrow.

III. Soil Erosion

A. In areas that have not been troubled by man, erosion of the soil is a slow process.

1. Shrubs and trees above the ground, and their roots below the ground, help prevent the soil from being washed away by running water.
2. The little soil that is carried away is replaced by new soil formed over the years.

B. When man uses the soil to grow crops, erosion can take place very quickly.

1. Almost all the shrubs and trees that protected the soil have been removed.
2. This removal makes it easy for the forces of erosion to work on the soil.

C. The most powerful force of soil erosion is running water.

D. Erosion of the soil starts when the rain begins to fall.

1. The raindrops strike the earth and loosen the soil.
2. Particles of soil may then be splashed away.
3. This kind of erosion is called **splash** erosion.

E. When the rain falls steadily, the soil absorbs the water until it can hold no more.

1. When this absorption takes place, the water runs off in broad sheets, carrying soil with it.
2. This kind of erosion is called **sheet** erosion.
3. Sheet erosion can take away all of the topsoil, leaving the subsoil—or even bare bedrock—behind.

F. As the water runs off, it eventually collects into small streams that flow down to lower ground.

1. As a stream travels, it may wash out some of the ground and form a small channel, called a **rill**.
2. A rill is often formed when crops have been planted in rows that run up and down a field that slopes.
3. A rill can become deeper and wider with each rainfall, as the running water carries more soil away each time, forming a larger channel, called a **gully**.
4. This kind of erosion is called **rill** or **gully** erosion.

G. The small streams flow into larger streams, each taking away soil from the bottom and sides of the bed upon which the stream flows.

IV. Methods of Preventing Soil Erosion

A. Unless something is done to stop soil erosion, the soil will soon become completely worthless for growing crops.

B. There are many ways to slow down soil erosion, especially where the land slopes downward.

C. In **contour plowing** the rows of crops follow the contours of the land.

1. This form of cultivation means that on hills the rows run sideways rather than up and down.
2. Rows that run sideways slow down the water as it flows down the hill.
3. These rows catch the soil and stop it from being carried away.

D. **Terracing** is used when the slope or hill is rather steep.

1. Steplike ridges, called **terraces,** are built, which follow the contours of the hill and run sideways.
2. These terraces either hold or slow down

the water sufficiently for it to soak into the soil so that the soil is not washed down the hill and carried away.

E. Strip cropping is used on milder slopes.
  1. In strip cropping different crops are grown on the same piece of land.
  2. First there is a plot of row crops, such as corn, where the plants are grown in rows.
  3. Next there is a plot of cover crops, such as grass or hay, where the plants cover the ground.
  4. The cover crops catch and hold any soil that may be washed away from the rows.
  5. The next year the cover crops are grown where the row crops were grown, and the row crops are grown where the cover crops were grown.

F. Bare land, unsuitable for growing crops, is planted with trees and grass to help replace the soil that was washed away.

G. In dry parts of the country as well as those parts where it has not rained for a long time, the wind can erode the soil.
  1. When the land has become really dry and bare and there are no crops on it, the wind can produce large dust storms.
  2. Erosion of this kind will often occur when the grasslands in rather dry areas are plowed up and crops are planted.
  3. When there is very little rainfall and no grass to hold the soil, the wind blows away the soil easily.

H. Sometimes trees are planted close together in rows to form a **shelter belt** for the farms.
  1. When the wind travels across the land, it is forced upward by one shelter belt after another.
  2. This forcing of the wind upward stops the wind from staying close to the ground and blowing the soil away.

V. Enriching the Soil

A. There are many minerals in the soil that growing plants need to make food.

B. The most important of these minerals are those that have nitrogen, phosphorus, potassium, calcium, and magnesium in them.

C. The plants take away large amounts of these minerals from the soil each year, which must be replaced if the soil is to stay fertile.

D. One of the best ways to replace these minerals is to use a natural fertilizer, such as animal manure, which adds both minerals and humus to the soil.

E. Another way is to use commercial fertilizers, which contain the minerals that plants need to grow.

F. A third way is to change crops every few years.
  1. Certain crops need different kinds and amounts of minerals from other crops.
  2. If the same crops are grown year after year, all of these minerals are taken from the soil, and only by using large amounts of fertilizer can the farmer continue to grow these crops.
  3. By growing different crops every few years, which need different kinds and amounts of minerals, the soil can get back the minerals it has lost.

G. When the soil becomes low in nitrogen, the farmer can grow such crops as clover, alfalfa, beans, or peas.
  1. These plants have little, round bumps attached to their roots.
  2. In the bumps there live certain bacteria, called **nitrogen-fixing bacteria.**
  3. Although 78 percent of the air is nitrogen, plants cannot use this nitrogen in the gaseous form in which it is found in the air.
  4. However, the nitrogen-fixing bacteria take the nitrogen from the air and change it into materials that plants can use.

VI. Testing the Soil

A. Soil is often tested to see what must be done to it to grow better crops.

B. Soil is tested to find out what minerals are

needed and what kinds of plants or crops will grow best in the soil.

C. Soil is also tested to find out whether it is too acid or alkaline.
   1. Some plants or crops grow better when the soil is slightly alkaline, and other plants or crops grow better when the soil is slightly acid.
   2. If the soil is too alkaline, an acid material is added to it.
   3. If the soil is too acid, an alkaline material is added to it.
   4. One alkaline material used to cut down the acidity of the soil, or "sweeten" it, is lime.

D. The amount of humus in a soil is found by heating a sample of the soil.
   1. Only the humus in the soil will burn away.
   2. By weighing the soil before and after it was heated, the loss in weight will indicate how much humus there was in the soil.

E. Tests can also be made to see how quickly water can go into or leave the soil, and how much water the soil can hold.

THE HISTORY OF THE EARTH

I. How Geologists Learn About the Earth

A. The history of the earth is recorded in the rocks.

B. This is the reason why geologists spend much time patiently studying rocks over the earth, looking for clues that will help them learn the complete history of the earth.
   1. They examine the rocks carefully for information about changes in the earth's surface.
   2. They look for evidence of change in climate.
   3. They also look for signs and traces of living things that lived long ago.

C. Although there are still a few gaps, geologists have managed to fit together the pieces of information they have collected and obtain a fairly complete history of the earth.

D. The following three areas of geology have helped geologists obtain this history: **stratigraphy, petrology,** and **paleontology.**

E. Stratigraphy is the study of rock layers.
   1. The order in which layers of rock are found is a very important clue to the earth's past.
   2. These layers are usually formed horizontally, with the oldest rocks on the bottom and the youngest rocks on top.
   3. If these layers are not disturbed, geologists can tell by the position of these layers how and when they were formed.
   4. Even when the layers are folded and faulted, or the rocks in the layers have been changed to metamorphic rock, geologists can still identify them, knowing that one layer of rock is older than the layer above it.
   5. These layers tell geologists where earlier oceans, mountains, plains, and plateaus were located.
   6. They also show the kinds of changes that took place on the earth's surface long ago.
   7. By matching layers of the same age that are located in different parts of the earth, geologists have been able to learn about the entire earth, rather than just one part of the earth.

F. Petrology is the study of the rocks themselves.
   1. Geologists study the rocks to learn how they were formed, what happened to them, and what kinds of minerals are in them.
   2. Every rock tells a story through its

structure, texture, physical and chemical makeup, and traces of former plants and animals embedded in it.

3. A piece of old sandstone may have ripple or wave marks on it, or there may be seashells in it, showing that the sandstone was formed in the ocean.
4. A conglomerate rock may show that it was made by a swiftly moving stream or by heavy ocean waves.
5. The earlier existence of shallow seas, lakes, deserts, glaciers, and other forms of the earth's surface can all be learned from the sediments they left behind.
6. These sediments can also tell us what kinds of rocks there were a long time ago, the climate at that time, and other conditions on earth a long time ago.

G. Paleontology is the study of fossils, which are the remains or traces in sedimentary rocks of earlier plants and animals.

1. The remains may be bones and teeth, or they may be the complete plants and animals themselves.
2. The traces may be footprints or body and tail marks.
3. Fossils are not found in igneous rocks.
4. Fossils can be found in sedimentary rocks that were changed to metamorphic rocks, but most fossils were usually destroyed or greatly damaged when the sedimentary rocks were changed.
5. From the sedimentary rocks the geologist can learn such things about living things of long ago as their development, body structure, nature habits, and the climate in which they lived.
6. If coral is found in the Arctic region, geologists know that at one time the climate was warm in this region.
7. If seashells are found on mountain tops, geologists know that at one time this land was under the ocean.

H. Fossils have been formed in many different ways.

I. Some animal fossils were formed when animals were covered by sediment.

1. Animals that lived in or near bodies of water sometimes were buried by the mud, dirt, and gravel.
2. This sediment then hardened into rock.
3. The hard parts of the body, such as the skeleton and teeth, were preserved in their original form in the rock.

J. Some animals fell into tar pits, swamps, or quicksand, which later hardened, and their bones and teeth were preserved.

K. Some fossils were formed when animals were frozen in ice and mud, and they were preserved whole.

L. Some insects became fossils when they were trapped by the sticky sap flowing from trees.

1. The insects became completely buried inside the sap, which then hardened.
2. The trees were covered with sediment later and began to be changed into coal.
3. In the process the sticky sap was changed to the material we call **amber.**
4. The insects inside the amber dried out to almost nothing, but their bristles, wing scales, and thin outer skeleton were preserved as fossils.

M. Some plants and animals formed fossils by leaving a cast of their remains.

1. When the plants and animals were covered with sediment and died, their hard parts were left behind.
2. The water inside the sediment dissolved these hard parts, leaving a hollow space in the sediment that surrounded these parts.
3. The space then filled with minerals, which hardened to form a cast.

N. Many plants and animals have been preserved in great detail as fossils when they were petrified, or "turned into stone."

1. This petrification does not mean that the original material in the plant or animal was really changed into stone.
2. What actually happened was that, when the plant or animal was buried, the original material in the plant or animal was replaced, particle by particle, with minerals in such a way that an exact duplicate of the material was formed.

3. This substitution of minerals for the original materials has been so perfect in some cases that exceptionally clear and complete fossil specimens have been formed.

O. Animals without hard parts, such as jellyfish and worms, and also plants without woody parts often left fossil prints.
1. When these soft, living things were covered with sediment and the sediment hardened, their parts were chemically changed into carbon.
2. This carbon formed an outline of the living things.
3. Even the delicate outlines of fish scales and leaf veins can often be seen in these prints.

P. Fossils of footprints, body and tail marks, outline and vein pattern of leaves, and imprints of stem and flowers have been formed.
1. These marks were first made in soft mud.
2. Later, soil or silt may have been gently blown or washed into these prints.
3. More layers of sediment were added, and eventually the mud and sediment hardened into rock, preserving at the same time the marks and imprints in the original mud.

Q. Fossils are often found in coal, especially soft coal.
1. Coal itself is the fossil remains of plants and trees that lived long ago in swampy land that was slowly sinking.
2. These plants and trees were buried under layers of sediment.
3. Under great heat and pressure, the plant materials were changed and hardened into coal.
4. Some of the original plant material can still be found as fossils in the coal.

II. How Geologists Calculate the Age of the Earth

A. Geologists have used many methods to find out the age of the earth and the rocks in it.

B. One method to determine the age of rock is to use the rate of erosion of soil.
1. Careful scientific observations show that, on the average, erosion of rock and soil takes place at a rate of 1 foot in about 5000 years.
2. If we know this rate, we can estimate the age of the Grand Canyon.
3. In some places the grand Canyon is about 600 feet deep.
4. With erosion taking place at the rate of 1 foot in about 5000 years, it would take about 30 million years for the Colorado River to erode 600 feet of the Grand Canyon.

C. Another method to find the age of rock is to use the rate at which sediment is deposited and changed into sedimentary rock.
1. Geologists think that it takes between 5000 and 10,000 years for a layer of sedimentary rock 1 foot thick to be formed.
2. This method is not as accurate as the method of using the rate of soil erosion.

D. Some geologists have tried to estimate the age of the oceans by the amount of salt in the oceans.
1. First, the geologists find out how much salt there now is in the oceans.
2. Next, they find out how much salt is being carried by rivers into the oceans each year.
3. By comparing how much salt the oceans now have with how much salt they are getting each year, it is possible to estimate how many years the oceans have been receiving salt.
4. This method is not very accurate because the oceans most likely received less salt in the beginning than they do today.

E. The older methods described above are not too accurate, and they are of little use in finding the age of the earth itself.

F. Geologists now use the newer method of radioactivity to calculate both the age of rocks and the age of the earth.

G. One radioactive method involves the

study of the uranium found in igneous and metamorphic rocks.

1. Uranium is a radioactive chemical element that breaks down very slowly to form other elements.
2. It breaks down to form radium, which in turn breaks down into a number of other elements, and finally it becomes lead.
3. Uranium breaks up at a very slow and steady rate, which cannot be changed by temperature or pressure.
4. Scientists have calculated that it takes 5 billion years for half a piece of uranium to be changed into lead.
5. By examining a piece of rock that has uranium in it and comparing the amount of uranium still present with the amount of lead that has been formed from the uranium, geologists can calculate the age of the rock—and even the earth—quite accurately.

H. By using this radioactive method, geologists estimate that the earth is at least 4 billion, and most likely 5 billion, years old.

I. Another radioactive method involves the study of radioactive carbon-14, which is found in sedimentary rocks.

1. All living things have carbon-14 in them.
2. When living things die, no more carbon-14 is produced.
3. Instead, the carbon-14 begins to break down at a very slow and steady rate, just as uranium does.
4. Scientists have calculated that it takes about 5600 years for half a piece of carbon-14 to break down.
5. The fossil remains of living things, which once had carbon-14 in them, are found in sedimentary rocks.
6. By examining a piece of rock that has fossil remains and comparing the amount of carbon-14 in it with the amount of other elements that have been formed from the carbon-14, geologists can calculate the age of the rock.

J. The carbon-14 method is used to find the age of rocks to 25,000 years old, and the uranium method is used to find the age of older rocks.

III. The Geologic Timetable

A. Because the history of the earth involves such a long period of time, geologists find it convenient to use a special calendar, called a **geologic timetable**, when discussing what happened to the earth during that time.

B. The longest division of time in the geologic timetable is called an **era**.

C. Eras are broken down into smaller time units called **periods**, which are broken down still further into smaller units called **epochs**.

D. There are six major eras in the life of the earth; they are listed as follows.

1. Cenozoic era.
2. Mesozoic era.
3. Paleozoic era.
4. Proterozoic era.
5. Archeozoic era.
6. Azoic era.

E. The earliest era is the Azoic era, and the most recent era is the Cenozoic era.

F. Each era had its own periods and its own epochs.

G. Between each era tremendous geologic upheavals, or revolutions, took place.

1. New mountain ranges were formed.
2. Shapes of continents were changed, and shallow seas within the continents were either formed or drained off.
3. The circulation of the oceans and the atmosphere changed.
4. All these upheavals produced changes in climate, which in turn caused changes in the kinds of living things that lived on earth.
5. New forms of living things developed, which were better able to live in the new and different climate.
6. At the same time, older forms of living things, which could not adjust to the new climate, died.
7. As a result, each era usually had its own

special kinds of plant life (flora) and animal life (fauna).

H. There were also geologic changes between periods and epochs, but these changes were not as great or as violent as those between eras.

IV. The Azoic Era

A. The **Azoic** era began between 4 and 5 billion years ago, and it lasted for roughly 2 to 3 billion years.

B. This era is the time when the earth was formed.

C. At the end of the Azoic era there was nothing on earth but rocks, water, and air.

V. The Archeozoic Era

A. The **Archeozoic** era began about 2 billion years ago, and it lasted for about 1 billion years.

B. During this era there was volcanic activity everywhere, great mountain ranges were formed, and the oceans took turns covering the land areas and then withdrawing.

C. Some Archeozoic rocks contain much graphite, the form of carbon that is used in pencils and as a lubricant.

D. Very simple forms of life, such as the tiny, one-celled plants called bacteria and algae, may have existed during this era.

VI. The Proterozoic Era

A. The **Proterozoic** era began roughly 1 billion years ago, and it lasted for about 450 million years.

B. During this era the basic shapes of the earth's continents developed, vast masses of igneous rock were formed, and there is evidence that glaciers may have been present.

C. Also, during this era most of the simpler animals without backbones, called **invertebrates**, made their appearance.

1. These included protozoa, sponges, jellyfish, coral, and animals that had a wormlike appearance.
2. There were also the beginnings of more advanced invertebrates, such as crabs, spiders, and insects.

D. There was not much plant life during this era.

1. Most of the plants belonged to the simplest group of plants, called **thallophytes.**
2. These included bacteria, blue-green algae, and the brown algae or seaweed.

E. Almost all of the living things in this era were found in the ocean.

VII. The Paleozoic Era

A. The **Paleozoic** era began about 550 million years ago, and it lasted for about 350 million years.

B. This era is called the **Age of Invertebrates, Fishes, and Amphibians.**

C. During this era many geological developments took place.

1. At the beginning of the era large parts of the North American continent were covered by shallow seas.
2. The Green Mountains in Vermont were then formed, as well as mountains in northern Maine and eastern Canada.
3. Thick beds of salt were formed in New York, Pennsylvania, West Virginia, Ohio, and Michigan.
4. The Appalachian Mountains appeared, and the shallow inland seas of eastern North America drained off, never to return.
5. The Alps in Europe and the Ural Mountains in Russia were also formed during this era.

D. Invertebrate life flourished in the early part of the Paleozoic era.

1. These animals included sponges, corals, worms, snails, starfish, and crabs.
2. Most of these invertebrates looked different from the kinds we see today.

E. The most common invertebrate during

this era was the trilobite, which was an early ancestor of the crab and lobster family.

1. The trilobite had a shell that was divided lengthwise into three clearly notched lobes or sections.
2. They had jointed legs that they used for walking on the ocean floor.
3. They had eyes and feelers that helped them find food, although some trilobites had no eyes.
4. Most trilobites were less than 3 inches long, but some were more than 2 feet long and may have weighed as much as 15 pounds.
5. They ate small organisms and decaying plants and animals.
6. Trilobites died out and became extinct at the end of the Paleozoic era.

F. During the middle of this era a large number of fishes of different kinds began to appear.

1. These fishes were the first animals with backbones, which are called **vertebrates.**
2. These fishes included armored fish, the ancestors of sharks, and fish with lungs called lungfish.

G. At the same time, plants began to appear on land.

1. Mosses, ferns, and seed plants grew, first beside oceans and lakes and then further inland.
2. Some fernlike trees grew to heights of 40 feet.

H. With the appearance of plants on land, animals began to live on land too.

1. These animals included scorpions, snails, spiders, and many kinds of insects.
2. There were hundreds of different kinds of cockroaches, some of them 4 inches long.
3. There were also dragonflies with a wingspread of 2 feet.

I. Coal was formed during this era, especially in the Pennsylvania area.

1. At this time there were large swampy forests, where a wide variety of land plants grew.
2. These plants included scale trees, horsetails, huge mosses and ferns, seed ferns, and plants that produced a primitive kind of cone.
3. The land in some of these forest areas sank very slowly and gradually so that huge piles of dead plants accumulated.
4. These piles of plants were slowly covered with water, which helped preserve them.
5. These areas of land kept sinking until they were far below sea level and were covered with layers of sediment hundreds of feet thick.
6. The weight of these layers produced much pressure and heat, which changed the plant material into coal.
7. This coal was soft coal, which was later changed to hard coal by more heat and pressure caused by forces acting inside the earth.

J. Amphibians that were the ancestors of our frogs and toads appeared toward the middle and end of this era.

K. The beginnings of reptile life also appeared toward the end of this era.

L. Two important lines of reptiles developed at this time.

1. The root reptiles were probably the ancestors of our reptiles today.
2. The mammal-like reptiles had teeth and skulls very much like those of mammals, and most likely they were the ancestors of the mammals.

VIII. The Mesozoic Era

A. The **Mesozoic** era began about 200 million years ago, and it lasted for about 140 million years.

B. This era is called the **Age of Reptiles.**

C. Many land and water changes took place in this era.

1. The shape of North America was very much like it is today, and the land for the most part was high and dry.
2. The Palisades were formed along the Hudson River, and they were really

mountains, which gradually have been worn down.

3. The Sierra Nevadas and the Rocky Mountains in North America and the Andes Mountains in South America were formed.
4. The Appalachian Mountains were worn down until they had become a fairly level peneplane, but toward the end of the era they were lifted up again, although not as high as they had been originally lifted.

D. Marked changes in plants took place.
1. In the beginning of this era the land was covered with cycads, which were palmlike seed plants that produced flowers that were not true flowers.
2. Conifers, which include pine, cedar, spruce, juniper, and cypress trees, were common in this era.
3. There were also ginkgo trees, which grew seeds but not flowers.
4. The giant mosses and ferns died out and were replaced by the flowering plants, such as oak, elm, maple, birch, and beech trees.
5. The grasses and grain plants also made their appearance at this time.

E. During this time the reptiles flourished and became highly specialized.

F. The most well-known of these reptiles were the huge dinosaurs.
1. The word dinosaur means "terrible lizard."
2. These reptiles left many of their bones and teeth behind as fossils, which explains why we know so much about them.

G. There were all kinds of reptiles, and they lived on land, in the oceans, and in the air.
1. Some were very large, and others were quite small.
2. Some ate only plants, and others ate flesh.

H. The **Brontosaurus** was about 65 feet long and weighed about 30 tons.
1. It had a long, thin neck and a tiny head.
2. Its legs were the size of thick tree trunks, and it had a very long tail.
3. It had a very tiny brain that weighed less than a pound.
4. It was amphibious, living both on land and in water.
5. It walked on all four feet, and it ate plants.

I. The **Diplodocus** looked like the Brontosaurus, but it was even longer.

J. The **Stegosaurus** had a double row of triangular bony plates that ran from its small head almost to the end of its tail.
1. Near the end of its tail there were two pairs of large, sharp, bony spikes.
2. It had a heavy body with short, thick front legs, and it ate plants.

K. The **Triceratops** was protected in a different way.
1. There were two sharp horns on top of its head and a third on its nose.
2. Over its neck there was a strong frill of bony plates connected to its head.

L. The **Tyrannosaurus** was about 50 feet long from head to tail and about 20 feet tall when it stood on its hind legs.
1. It had small front legs, and it could stand erect, using its tail to balance it.
2. It had a large head that was roughly 4 feet long, filled with sharp teeth that were 6 inches long.
3. It was a meat-eating reptile.

M. In the sea there were crocodiles, turtles, and other kinds of reptiles.
1. The **Ichthyosaurs** were long, fishlike reptiles that used their feet and tails as paddles for swimming.
2. The **Plesiosaurs** were long, slender reptiles with necks that looked like snakes.

N. The **Pterodactyls** were one kind of reptile that flew in the air.
1. They had a wide piece of skin connected from the very long joints of their fourth finger of each front leg to their body near the hip.
2. The Pterodactyls were not true birds, and they glided rather than flew.

3. They were all different sizes, some as large as a sparrow, and others with a wingspread of 20 feet or more.
4. They all ate flesh.

O. The first birds appeared during this era.
1. The birds developed from a different branch of reptiles than the Pterodactyls.
2. These birds were about the size of a pigeon.
3. Although their skeleton and teeth were like that of a reptile, their wings and body were partly covered with feathers.
4. These birds had fingers with claws at the end of each wing, jaws without bills, and teeth.

P. Toward the end of this era mammals began to appear.
1. They were small animals about the size of rats.
2. Although they looked like reptiles, they were real mammals because they were warm-blooded, covered with hair, and suckled their young.

Q. At the end of the Mesozoic era all the dinosaurs died out and became extinct.
1. Many theories have been proposed to explain why the dinosaurs died out.
2. One theory claims that their tiny brains, with resulting low intelligence, was responsible.
3. Another theory claims that the drying up of the swamps and the change in plant life made the dinosaur starve to death.
4. Another theory suggests that perhaps the growing number of mammals stole and ate all the dinosaur eggs.
5. Another theory proposes that, when the climate became very cold at the end of this era, the dinosaurs could not live in this new climate.

IX. The Cenozoic Era

A. The **Cenozoic** era began about 60 million years ago, and it has lasted until today.

B. This era is called the **Age of Mammals.**

C. Final land changes took place in this era.
1. The fourth and final glacial period carried over into this era.
2. During this glacial period there were four separate ice ages, where glaciers at the poles moved down and covered large parts of the earth's surface and then returned to the poles.
3. In this era the areas along the Atlantic coast, the Gulf of Mexico, and parts of the Pacific coast, which had been still under water, gradually became dry land.
4. Much volcanic activity took place in North America.
5. The Colorado plateau was lifted, and the Colorado River began cutting through it to form the Grand Canyon.
6. The Rocky Mountains and the Appalachian mountains were lifted, and the forces of erosion began working on them.
7. As erosion continued, great amounts of sediment were formed and deposited.
8. The remains of many plants and animals were embedded in these sedimentary layers and became fossils.

D. The plants slowly continued to develop until all the kinds we see today were formed.

E. There was a tremendous increase in the number and kinds of insects on earth.

F. The fishes developed into the fishes we see today.

G. The only reptiles left from the Mesozoic era included mostly crocodiles, alligators, turtles, lizards, and snakes.

H. Modern toothless birds with beaks appeared, and they grew in number and kind.

I. The mammals became larger, and they flourished until they covered the earth.

J. At first there were two kinds of mammals: those that laid eggs from which their young were born, and those that give birth to their young alive.
1. Today almost all mammals give live birth to their young.
2. Only a few, such as the duckbill and the spiny anteater, still lay eggs.

K. Some mammals, called **marsupials**, developed pouches for their young.
1. The young of marsupials are always born prematurely.
2. These premature young stay in the pouch, where they get warmth, shelter, and milk.
3. The kangaroo and opossum are marsupial mammals.

L. One group of mammals went back to the sea and spent all their time in the water.
1. This group includes whales, porpoises, and dolphins.
2. They have no hind legs, their forelegs are shaped like paddles, and their tail is like that of a fish.
3. Their young are born alive and are fed by their mother's milk, just like the young of mammals that live on land.
4. Some mammals like the seal and sea lion spend most of their time in the water.

M. Mammals like the bat developed flaps between their very long finger bones, and they were able to fly.

N. Many of the earlier mammals in the Cenozoic era died out and became extinct.
1. The **Smilodon** or saber-tooth tiger had two large teeth, or fangs, in its upper jaw.
2. The **Megatherium** was a giant sloth that stood about 20 feet high on its hind legs and weighed several tons.
3. The **Mastodon** looked like a large elephant, with hair that was coarse and wooly, and with very large tusks.
4. The **Mammoth** also looked like an elephant, but it had such big teeth that there were never more than eight teeth in its mouth at one time.
5. The **Canis Diris** looked like a wolf, and it was 6 feet long.

O. Many of the earlier mammals gradually developed into the mammals we know today.

P. The horse is an example of a present-day mammal that developed from an earlier mammal in the Cenozoic era.

Q. The first horse was called **Eohippus**, and it appeared early in the Cenozoic era.
1. It was very small, being about the size of a small dog.
2. It had a short neck, a few stiff hairs instead of a mane, and a short tail.
3. Its teeth were not suited for eating grass, and it ate leaves and shrubs instead.
4. It had four toes on each front foot and three toes on each back foot.

R. The Eohippus was followed by the **Mesohippus**.
1. The Mesohippus was larger, being about the size of a large dog.
2. It had a slightly longer neck, the beginning of a mane, and a longer tail.
3. It now had just three toes on each foot, and the middle toe was much larger than the other two.
4. When it walked or ran, all three toes touched the ground.

S. The **Meryohippus** came after the Mesohippus.
1. It was larger, and it had a longer neck, mane, and tail.
2. It still had three toes, but only the middle toe now touched the ground when it walked or ran.

T. Eventually the **Pliohippus** developed.
1. It was quite tall, with a good-sized mane and a long, flowing tail.
2. Its teeth had become specialized for biting and grinding the tough grass it now ate.
3. It had just one very large toe on each foot, and this toe helped it run more swiftly than its ancestors.
4. The other two toes had become very small, and they could not be seen because they were now inside the foot.
5. The nail of this very large toe became the hoof.

U. The present-day horse, **Equus**, followed not long after the Pliohippus.

X. The Age of Man

A. Some geologists include the history of man in the Cenozoic era.

B. Other geologists prefer to put man in a new era, called the **Psychozoic** era.

C. The Age of Man began about a million years ago.
   1. Crude tools made of flint have been found, which date back to this time.
   2. These sharp-edged stones are called eoliths, and they were shaped to fit the hand.

D. Very few fossils of early man have been found, and these fossils are mostly skulls and bones of arms or legs.

E. From these fossils geologists have gained some idea of what early men must have looked like.

F. The first remains of earliest man were found in Java in 1891.
   1. Only the top of the skull, three teeth, bits of nose bones, and a thigh bone were found.
   2. However, from these pieces scientists were able to picture what this early Java man looked like.
   3. He had apelike features, such as a low, flat forehead, a thick skull, and brow ridges or thick ridges of bone that jutted above the eyesockets.
   4. Yet he was a primitive man because he stood upright and his brain case was much larger than that of an ape.
   5. Scientists estimate that the **Java man** lived about 500,000 years ago.

G. The remains of the **Peking man** were found about 1927 in a cave near Peking (or Peiping), China.
   1. The Peking man was very much like the Java man, but he had a bigger brain case.
   2. He knew how to use fire, and he is called the early Stone Age man because he used a wide variety of stone tools that were fairly well shaped.
   3. He made these tools by chipping away at pieces of stone, and he used them for chopping or scraping.

H. The remains of the **Neanderthal man** were found about 1858 in Neander Valley in Germany.
   1. He lived in Western Europe, North Africa, and parts of Asia about 200,000 years ago.
   2. Scientists believe that the Neanderthal man did not originate in Europe but came over from Asia, where he had developed from the Java man.
   3. He looked like the Java man, but he had a much larger brain case.
   4. He was the first man to be classified by scientists as a man, rather than an ape-man.
   5. He lived in a cave, hunted animals, used fire for cooking, and made much better stone spear points, hand axes, scrapers for animal skins, and other such tools.
   6. After the Neanderthal man lived for about 100,000 years, he became extinct, and no one knows how or why this happened.

I. The **Cro-Magnon man** is believed to be the ancestor of modern man.
   1. Five skeletons of the Cro-Magnon man were discovered about 1868 in the Cro-Magnon Cave in Southern France.
   2. Since then, many more fossils have been found in caves in France, Spain, Italy, and other parts of southern Europe.
   3. The Cro-Magnon man appeared about 50,000 years ago, and he lived in different parts of Europe, Africa, and Asia.
   4. He did not look like an ape at all, for he did not have the low brow, thick brow ridges, protruding chin, and receding jaw that the great apes have.
   5. He was tall, stood perfectly upright, and had a brain as large as modern man.
   6. He made excellent stone weapons and tools, hunted with a bow and arrow, and used animal skins for clothing.

J. The **Neolithic man**, also called the **Recent Stone Age man**, followed the Cro-Magnon man.
   1. He knew how to grind and polish stone and bone to make smooth, sharp tools.
   2. He tamed wild animals and kept them in herds to be used for work, food, and clothing.

3. He built his own shelter rather than look for a cave or other place to live in.
4. He joined with other men and lived in villages so that they could now protect themselves from enemies and from wild animals.

LEARNING ACTIVITIES FOR "THE EARTH"

THE COMPOSITION OF THE EARTH

1. *Origin of the earth* · Have the children read and then discuss the different theories about the origin of the earth. Observe a baked apple as it cools, or a plum that has dried up and wrinkled, and note the "mountains" and "valleys" that have formed on the earth's surface.

2. *The earth's layers* · Get a styrofoam ball at least 6 inches in diameter, and larger if possible. These balls are now sold as decorations for Christmas trees. By using a sharp knife, cut a good-sized wedge out of the ball so that the inside of the ball can be seen to the center (Figure 10–1). By using a soft pencil, draw lines on the inside of the ball to show the relative thickness of the earth's layers. Note that the relative thickness of the earth's crust will have to be exaggerated. Color these thicknesses with different colored wax crayons.

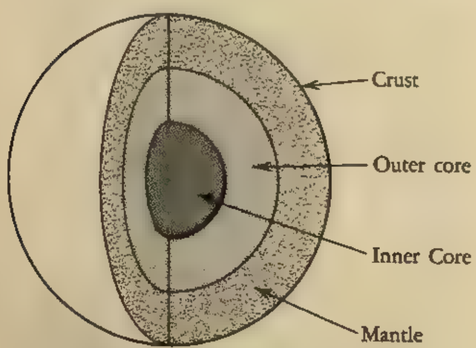


FIGURE 10–1.
MODEL OF THE EARTH'S LAYERS.

Rough cutouts of some of the earth's continents can be pasted on the outside of the ball to give the illusion that this is a model of the earth.

3. *Collect and observe rocks* · Collect samples of different kinds of rocks in your community. Good sources of rocks are river banks, farmers' rock piles, road cuts, excavations for large buildings, beaches, gravel pits, quarries, and mine dumps. Such equipment as a knapsack, old newspapers for wrapping up specimens, a geologist's hammer or a bricklayer's adz (which is much less expensive than the hammer), a large chisel, and a small chisel will be helpful. When breaking up rocks, first put them in a paper or cloth bag, or wrap them in newspaper, so that chips will not fly and cause cuts or damage to the eyes.

After the rocks have been collected, divide them into groups according to similarities of color, shape, material, and other characteristics. Observe the rocks individually and try to deduce as much as you can about them. Smooth, round rocks have most likely been acted upon by running water. Flat rocks are usually pieces of sedimentary rock. Pebbles and smaller rocks embedded or cemented in the rock will probably mean that the rock is a conglomerate. Crystals in the rock usually mean that the rock is igneous.

4. *Examine igneous rocks* · Obtain samples of such igneous rocks as granite, basalt, obsidian, and pumice. Examine them carefully with and without a magnifying glass. Igneous rocks are usually light colored or dark colored. Light-colored igneous rocks, like granite, are

made up mostly of such light minerals as quartz and feldspar, together with small amounts of dark minerals such as mica or hornblende. Dark-colored rocks, like basalt, are made up of such dark-colored minerals as hornblende, biotite, mica, or augite. Note the smooth, glassy appearance of obsidian. Its black color is because of the tiny specks of magnetite scattered through it. Observe how pumice is spongy and full of air holes. See if the pumice will float in water. It will float if there are enough air holes in it.

5. *Examine sand* · Examine sand closely through a strong magnifying glass. Note the presence of different minerals, with differences in color, shape, and size. The colorless glassy crystals are quartz. Red crystals are usually garnet. Flaky black crystals may be mica or biotite. Rectangular black crystals are probably hornblende. If there are black crystals that are attracted to a magnet, they are most likely magnetite. Green crystals may be olivine, and purple crystals may be amethyst.

6. *Examine sedimentary rocks* · Obtain samples of such sedimentary rocks as conglomerate, sandstone, limestone, shale, and rock salt. Examine them carefully with and without a magnifying glass. Look for grains of sand, silt, or clay. Find out how each of these rocks was formed.

7. *Test for limestone* · By using a medicine dropper, allow some vinegar or lemon juice to fall on a piece of limestone. Bubbling will take place. The limestone is made of calcium carbonate, which reacts with the acid vinegar or lemon juice to form carbon dioxide gas.

8. *Identify the cementing material of sandstone* · Pour a few drops of vinegar or lemon juice on the sandstone. If the material between the grains of sand bubbles, the cementing material is limestone. If the rock is yellow, brown, or red, the cementing material is most likely to be iron oxide (a compound made from iron and oxygen). If the sandstone is colorless, very hard, and does not bubble when vinegar is added, the cementing material is probably silica (quartz).

9. *Sediments settle in water to form layers* · In a 1- or 2-quart jar add pebbles or small stones, sand, and fine earth or silt until the jar is filled one third to one half. Add water until the jar is almost full, screw the cap on tightly, and then shake the jar and its contents. Put the jar down and allow the materials to settle. The heavier, coarser materials will settle to the bottom first, and the lighter finer particles will form a layer on top (Figure 10–2). If you wish, add a new layer of gravel (without water this time), then a layer of sand, then a layer of fine soil, and continue making layers until the jar is filled.

10. *Make artificial sedimentary rock* · Put some sand in a small cardboard container. Add a little Portland cement or plaster of Paris and mix well. Now add a little water, stir, and allow the mixture to dry. An artificial sandstone will be formed, with cement or plaster of Paris as the cementing material.

Press wet clay together hard and allow it to dry. A rocklike material, similar to shale, will be formed.

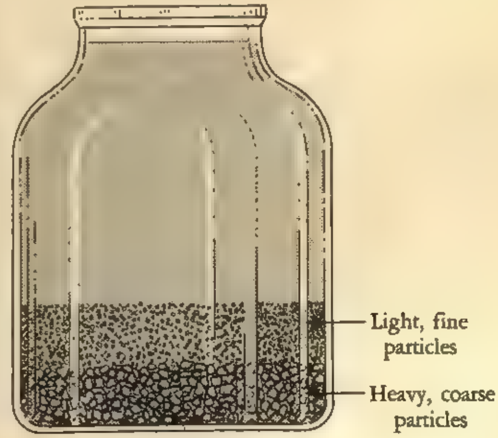


FIGURE 10–2.
HOW LAYERS OF SEDIMENT ARE FORMED IN WATER.

11. *Examine metamorphic rocks* · Obtain samples of metamorphic rocks, such as gneiss, quartzite, slate, and marble. Examine them carefully with and without a magnifying glass to help determine the composition of the rock. Test the rocks with vinegar or lemon juice to see if any were formed from limestone and, therefore, will bubble. Find out how each of the rocks was formed.

12. *Test rocks for hardness* · Use your fingernail, a penny, jackknife, steel file, and piece of glass to test rocks for hardness through number 7 on Mohs' scale. The scale shown in Table 10–1 can be used to classify rocks according to hardness.

TABLE 10–1. Classification of Rocks by Hardness

TEST	HARDNESS NUMBER
Rock is scratched easily by fingernail	1
Rock is scratched by fingernail	2
Rock is scratched by a penny	3
Rock is scratched easily by a knife blade	4
Rock is scratched by a knife blade	5
Rock is scratched by a steel file	6
Rock will scratch glass	7

13. *Test rocks for streaks* · Rub different rocks and minerals on a piece of unglazed porcelain tile, such as the back of a ceramic tile. Observe the streaks that are produced. Note that the streak is often a different color from that of the rock. Consult geology books for charts of streaks, and use the streaks as one of the clues in helping to identify the rocks and minerals.

14. *Test rocks for cleavage* · By using a hammer, strike rocks until they break, and then examine the pieces. Note that some rocks split easily along one or more plane and form flat, smooth surfaces in one or more direction. Other rocks do not have this property of cleavage, and, when they break, they form either rough, splintery surfaces or smooth, curved surfaces.

15. *Examine rocks for luster* · Examine rocks and minerals, noting their luster, which is the way they reflect the light that strikes them. Some rocks have a metallic luster whereas other rocks have a nonmetallic luster and may look waxy, glassy, pearly, greasy, silky, earthy, or dull.

16. *Flame and borax heat tests* · These tests are clearly described in most chemistry textbooks or laboratory manuals as well as in books on minerals. The children may be interested in using them to help identify some of the minerals.

17. *Examine rocks for crystal structure* · Break open rocks and examine them with a magnifying glass, looking for crystals of minerals in the rocks. Mineral crystals will be different in color, shape, and size.

18. *Form crystals* · Dissolve as much sugar as possible in a tumbler half-filled with hot water, stirring vigorously. Pour the sugar solution into a small, deep saucer and put a string into the solution, allowing the string to hang over the edge of the saucer (Figure 10–3). Place the saucer in a quiet corner and allow it to evaporate for a day or two. Crystals will form on the string and at the bottom of the saucer. Pour off any solution that remains, allow the crystals to dry, and examine the crystal structure with a magnifying glass or through the low-powered lens of a microscope. Repeat the experiment, using salt, borax, or alum, and compare the crystal structure in each case.

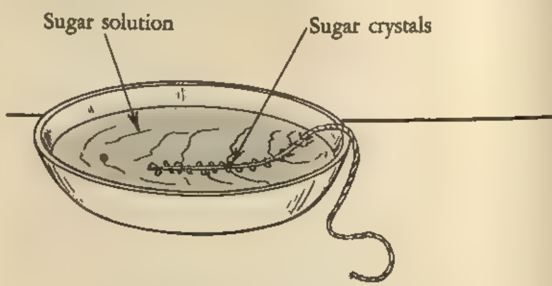


FIGURE 10–3.
FORMING SUGAR CRYSTALS.

19. *Extrusive and intrusive rock crystals* · Obtain some alum in the drugstore or grocery store. Dissolve as much alum as possible in each of two beakers almost full of hot water. Place one beaker in the refrigerator or surround it with ice so that the solution cools as quickly as possible. Place the other beaker in a quiet corner and allow it to stand overnight. Examine the crystals from both solutions the next day. The crystals from the alum solution that was cooled quickly are rather fine and small, like extrusive crystals, because the solution was cooled so quickly that large crystals were not able to form. The crystals from the alum solution that was allowed to cool slowly are much coarser and larger, like intrusive crystals, because the solution cooled gradually and allowed large crystals to form.

20. *Examine the original color of rock* · Because the surface of rocks and minerals becomes weathered, their color often becomes dull. Break up some rocks and minerals, first wrapping them in paper or cloth. Compare the color of the freshly broken surface inside the rock or mineral with that of the weatherbeaten outside.

21. *Study samples from mineral groups* · Excellent sets of minerals may be purchased from scientific supply houses and natural history museums. Obtain sets containing representative examples of silicious, nonmetallic, and metallic ore, and gem minerals. Have the children examine them and make a list of the properties of each group as well as the well-known members in each group. Note and compare similarities and differences.

22. *Display a rock collection* · Display local rocks that have been collected and identified. Cigar or shoe boxes, with a layer of cotton on the bottom, make excellent containers. The children can also use a block of styrofoam and press the minerals into the styrofoam so that they fit snugly and will stay by themselves. Even egg containers made of pressed cardboard can be used.

Number each rock permanently by painting numbers with bright red fingernail polish directly on each specimen. Some collectors prefer to put a small round coat of white shellac on each specimen and then write numbers on this coat with black India ink. Put a label with the number of the mineral and a description of the mineral next to the mineral in the container (or on a master sheet if there is no room). The description should include the name of the mineral, the place and date of collection, and the name of the collector.

23. *Make artificial rocks* · Place a small portion of plaster of Paris, Portland cement, and plasterer's lime in three paper cups. Add just a little water to each cup, stir, and set the cups aside for the materials to harden. After a few days tear the paper away and examine the artificial rocks that have been made. Concrete can be made by using three parts of sand to one part of Portland cement and adding enough water to form a thick, creamy mixture. Pour the mixture into a waxed milk carton, let it set for a few days, and then tear the cardboard away.

24. *Uses of rocks* · Examine buildings (including your own school building) and places where natural rocks have been used for construction purposes. You should find such natural rocks as marble, granite, limestone, lannon stone, and slate.

25. *Use of minerals* · Read about the different kinds of uses in the United States for mineral ores. Obtain or draw a map of the United States and label the location of important mineral deposits. Discuss the need for and importance of the conservation of our mineral resources.

FORCES THAT SHAPE AND CHANGE THE EARTH'S SURFACE

1. *Illustrate the theory of isostasy* · Obtain two large, spiral notebooks the same size and

thickness, and place one on each pan of a platform balance so that the notebooks are almost touching (Figure 10–4). The notebooks will

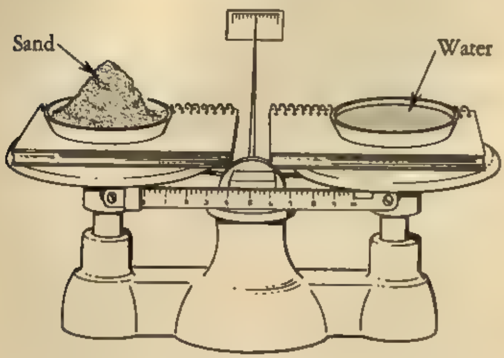


FIGURE 10–4.
HOW THE THEORY OF ISOSTASY EXPLAINS MOVEMENTS OF THE EARTH'S CRUST.

represent the earth's crust, and the pages the layers that make up the earth's crust. Place a pie tin on each notebook. In one tin put some water, which represents the oceans. Make a "mountain" of sand in the other tin, adding just enough sand to balance the water. Now take a teaspoon of sand away from the "mountain" and add it to the "ocean" to show that the mountain rock is worn away and carried down to the ocean. The higher "mountainous" region now becomes lighter and rises slowly while the lower "oceanic" region becomes heavier and slowly sinks.

2. *Illustrate the contraction theory of earth surface movement* · Let a hot baked apple cool or a fresh plum dry up. The fruit will contract and produce wrinkles and folds, which would correspond to the formation of mountains and valleys as the earth continues to contract.

3. *Illustrate the convection theory of earth surface movement* · Fill a Pyrex pot with water and add shredded blotting paper to the water. Muddle and stir the blotting paper until most of it settles to the bottom. Place the pot on a hot plate in such a position that only one side is in contact with the heating element (Figure 10–5). Now heat the pot of water. As the water heats up and boils, a convection current will be set up and the blotting paper will trace the route of this convection current. The hotter, lighter water rises, and the colder, heavier water falls. Inside the earth the rock is under great pressure and can move just like a liquid. Convection currents may also take place inside the earth and in this way affect the earth's crust.

4. *Discuss the continental drift theory of earth surface movement* · Observe a globe of the earth or a world geologic map. Note how, if North and South America were moved eastward against Europe and Africa, the shapes of the continents would match quite well. Madagascar would fit well against the east coast of Africa. Point out that if the earth were one continent that broke up, the drifting parts could push against the ocean basins, as they came to rest, and form mountain ranges.

5. *Folding* · Fold three differently colored towels until they are long and narrow and then place one on top of the other to represent layers of rock. Now place one hand near each end of the pile of towels and push sideways

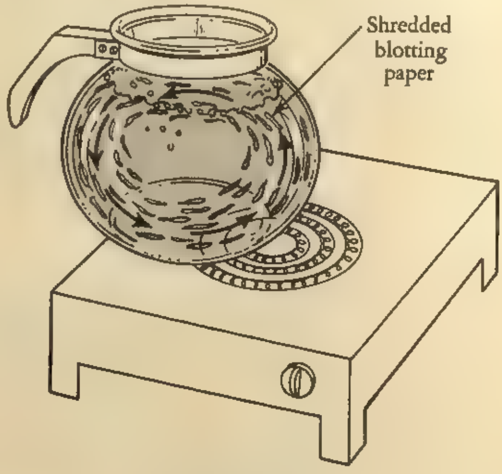


FIGURE 10–5.
A CONVECTION CURRENT.

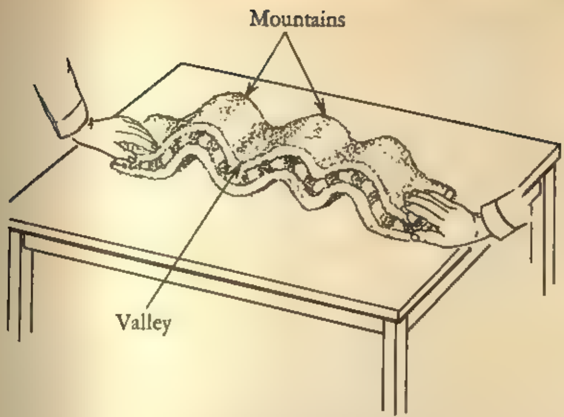


FIGURE 10–6.
HOW FOLDING PRODUCES MOUNTAINS AND VALLEYS.

toward the middle (Figure 10–6). Wavelike folds will form with a crest (anticline) and a trough (syncline), producing mountains and valleys.

6. *Faulting and earthquakes* · Place one palm of your hand on top of the other, as shown in Figure 10–7, with the heel of one palm pressed hard against the other. Both palms will represent a layer of rock pushing against the other in opposite directions. Now push both palms hard in opposite directions. There will be a sudden movement as the "layers of rock" slide over one another, producing an earthquake.

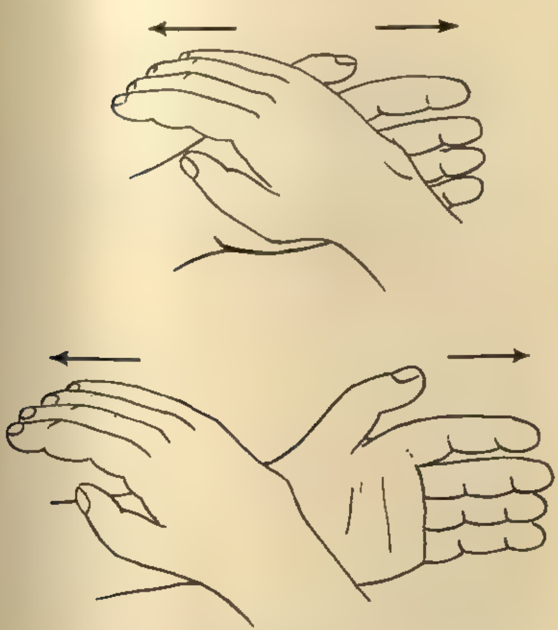


FIGURE 10–7.
HOW FAULTING PRODUCES EARTHQUAKES.

7. *Earthquake belts* · Obtain a world geologic map or a globe of the world and trace the two large earthquake belts. Note the countries that are included in these belts. Read about or recall earthquakes that took place in these countries recently. Point out that volcanoes usually occur within the earthquake belts.

8. *Tsunamis* · Have the children read about tsunamis that have taken place in the past. Point out that tsunamis are not tidal waves, but they are huge waves caused by earthquakes that began under the ocean.

9. *Mountain formation* · Make models showing the four common ways that mountains are formed. Place a card in front of each model, explaining the kind of mountain it is and where it can be found in the United States. Repeat Learning Activity 1 on Isostasy (p. 323) to show how block mountains are formed, and Learning Activity 5 on Folding (p. 324) to show how folding mountains are formed.

10. *Valleys* · Make models showing the life cycle of a valley.

11. *Plains and plateaus* · Read about and discuss the difference in formation between coastal plains, lake plains, and plateaus. Trace the life cycle of a plateau, and show pictures of mesas and buttes.

12. *Make a "volcano"* · Invert a flower pot and cover it with modeling clay to make a volcanic cone (Figure 10–8). Use green or brown clay to represent the earth, and red clay "rivulets" to represent the flow of lava. Have the crater extend above the pot so that the crater

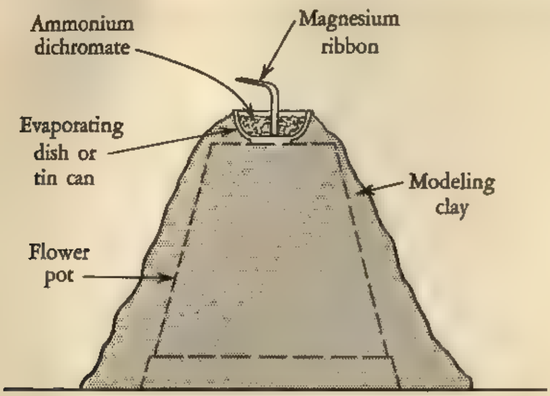


FIGURE 10–8.
A SIMULATED ERUPTING VOLCANO.

is 2 to 3 inches across and about 1½ inches deep. In the crater insert a small porcelain evaporation dish or a small frozen fruit-juice can, whose sides have been cut down with tin snips so that the can is only 1½ to 2 inches high. Surround the can completely with the modeling clay.

Pour 1 tablespoon of ammonium dichromate into the crater. Cut a strip of magnesium ribbon 3 inches long and place it upright into the ammonium dichromate so that one end is in the chemical and the other end extends above the crater. Now apply lighted wooden matches repeatedly (and patiently) until the magnesium ribbon catches on fire. If magnesium ribbon is unavailable, put 10 drops of lighter fluid or alcohol on the ammonium dichromate crystals and apply a lighted match. The magnesium burns with a hot, white flame and sets off a rapid chemical reaction in which the ammonium dichromate decomposes. The "volcano" erupts, sparks shoot up into the air, and a green fluffy material (representing lava) is formed. If the room is shaded or in semidarkness, the effect will be more pronounced. Let the "volcano" cool for half an hour before cleaning it. Be sure to point out that in a real volcano the eruption takes place because of pressures inside the earth, which force magma upward and out through a crack or weak spot in the earth's crust.

13. *Why volcanoes erupt* · Let the toothpaste in a tube represent magma. Squeeze the toothpaste hard and insert a pin into the metal (which represents the earth's crust). This fault or crack in the "earth's crust" allows the "magma," which is under pressure, to flow up and out.

14. *Volcanic rock* · Show samples of volcanic rock, such as lava, obsidian, and pumice. Point out that where lava cooled quickly, there was no time for crystals to form, and a glassy rock resulted. Where lava could cool slowly, large crystals were formed. The holes in pumice are caused by the presence of hot gases in the lava that did not have time to escape and were trapped inside the lava.

15. *Kinds of volcanoes* · Read about and list the names of well-known active, dormant, and extinct volcanoes throughout the world.

16. *How geysers erupt* · Place a short-stem funnel in a Pyrex beaker and add water until the bowl of the funnel is covered and the water is level with the beginning of the stem (Figure 10–9). Heat the beaker on a hot plate. When the water begins to boil, the bubbles of steam expand and rise, pushing the water up the stem and making it spout like a geyser.

17. *Taking a field trip* · Visit geologic exhibits in natural history museums and college museums to observe and study rocks, models of land forms, and fossils.

FORCES THAT WEAR AWAY THE EARTH'S SURFACE

1. *Rocks wear away other rocks* · Obtain a rock that crumbles or breaks rather easily and, while holding it over a sheet of white paper, rub it against a larger, harder rock. Note the rock dust that is worn off and falls on the paper. See how this dust compares with a pinch of soil.

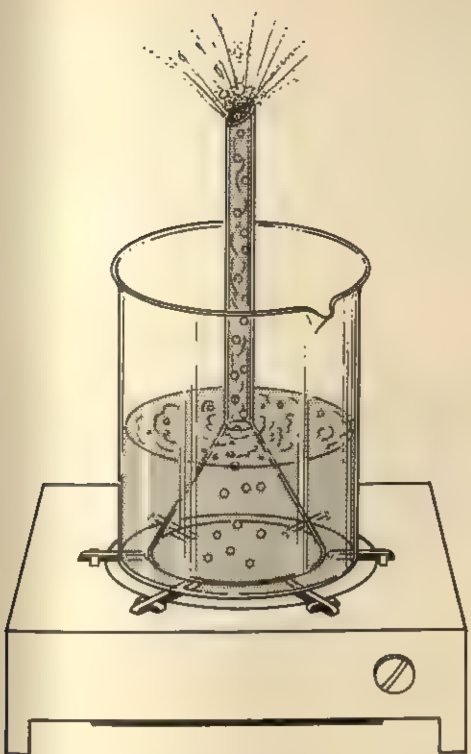


FIGURE 10–9.
A FUNNEL GEYSER.

2. *Water wears away rock* · Obtain a large rock that crumbles or breaks rather easily and break it up into smaller pieces. Note the rough appearance of the pieces, especially at the edges. Place some of these pieces into a glass jar, add water until the jar is about half-filled, and screw the cap tightly on the jar. Have the children take turns shaking the jar until their arms become tired. Now remove the pieces of rock from the jar, but leave the water in the jar. Note how much smoother the sharp edges of the rocks have become. Also note the sediment that settles to the bottom of the jar.

3. *Roots crack and break up rocks* · Look for sidewalks that have been pushed up, cracked, or broken by the roots of nearby trees.

4. *Changes in temperature crack rocks* · Obtain a piece of shale or other sedimentary rock that is thoroughly dry. Hold one end of the rock with forceps and heat the other end strongly in a Bunsen burner flame (Figure 10–10). After the end of the rock has been heated for some time, plunge this end quickly into a beaker or wide-mouthed jar full of cold water. As the rock contracts because of the sudden change in temperature, bits of the rock will break off and settle to the bottom.

5. *Many rocks are porous* · Dip a piece of dry sandstone or limestone into water for a few moments and then lift the rock out and wipe it with a soft, absorbent cloth. The rock will still look wet. Weigh a piece of dry sandstone and then immerse it in a jar of water overnight. Remove the sandstone, wipe it dry, and weigh it again. The porous sandstone will be heavier because of the water it has absorbed.

6. *Freezing water cracks rocks* · Fill a 2- or 4-ounce glass medicine bottle full of water, wrap it in a small towel or cloth, and leave it overnight in the freezing compartment of a refrigerator. The next day remove the cloth and examine the bottle. The freezing water expanded and broke the glass. When water in porous rocks freezes, the rocks often are cracked in the same way.

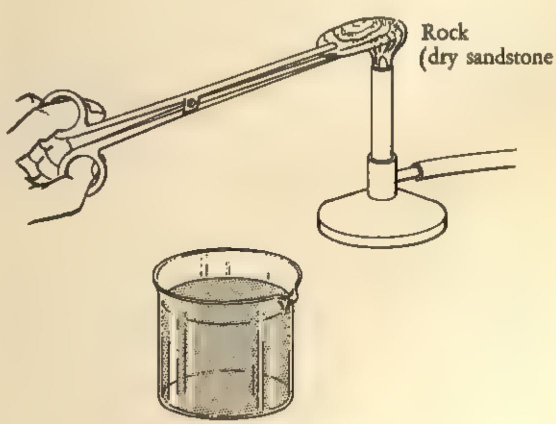


FIGURE 10–10.
HEATING, FOLLOWED BY SUDDEN COOLING, BREAKS UP ROCK.

7. *Wind wears away rocks* · Many stones and large rocks in the desert show the effects of wind-borne sand, which has worn away their surfaces. Point out that man uses sandblasting to clean stone buildings.

8. *The oxygen in the air affects rocks* · Place a wad of steel wool outdoors for a few days and note how rusty it becomes. Many rocks contain chemicals that react with the oxygen in the air and make them crumble.

9. *Carbon dioxide forms an acid with water* · Obtain some distilled water or freshly collected rainwater. Test the pure water with litmus paper for acidity. Now blow for quite some time through a straw into a glass of this water. Test again with litmus paper. This time the litmus paper will turn red, showing the presence of carbonic acid that was formed when the carbon dioxide from the air in your lungs dissolved in the water.

10. *Lichens crumble rock* · Find rocks on which lichens are growing. Scrape off a bit of lichen and examine the rock underneath it. This part of the rock is softer and more crumbly than the rest of the rock because the lichen gives off an acid that attacks the rock.

11. *Examine weathered rock* · Compare the surfaces of new and old buildings that have been constructed with the same kind of rock. Headstones in cemeteries show the results of weathering. Break open a weathered rock, wrapping it in cloth or paper first, and note how weathering has dulled or changed the color of the outside of the rock.

12. *Groundwater dissolves limestone* · With a can opener remove the top and bottom of a tin can. Cover one end of the can with a piece of cotton cloth or several layers of cheesecloth, and fasten the cloth securely to the sides of the can. Fill the can with crushed limestone and, while holding the can over a shallow saucer, pour distilled water or freshly collected rainwater into the can (Figure 10–11). Collect a sizable quantity of the water that has passed through the can and fallen into the saucer. Place the saucer, together with another saucer of the same size and containing an equivalent amount of distilled water or rainwater, in a quiet place and allow the water in both saucers to evaporate completely. The water that passed through the limestone will leave behind a coating of limestone when it evaporates.

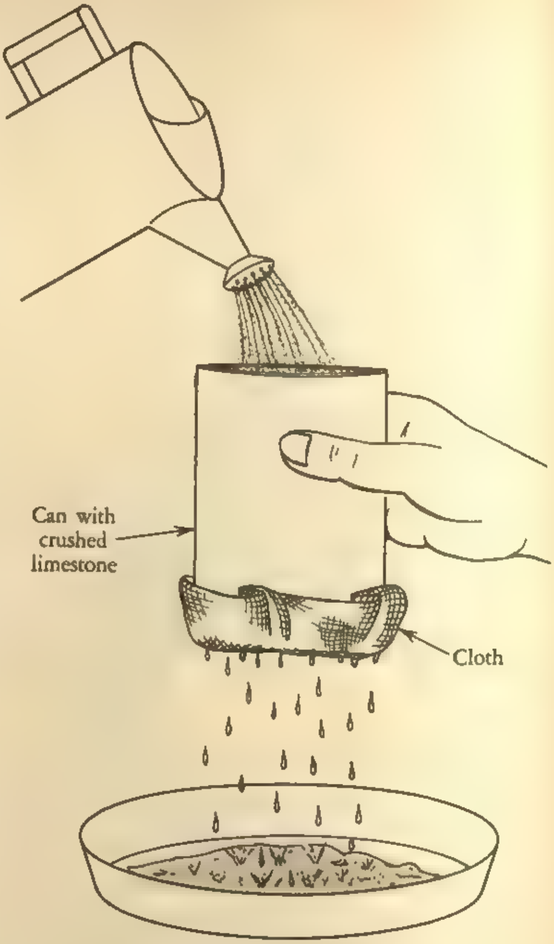


FIGURE 10–11.
WATER DISSOLVES LIMESTONE.

13. *Caves* · Show pictures of caves or caverns that have been formed by the action of groundwater, containing carbon dioxide, on the limestone. If possible, visit a nearby cave and examine its formation.

14. *Stalactities and stalagmites* · Obtain some epsom salt or alum and dissolve as much of the salt as possible in each of two glasses of water resting on a piece of cardboard. Place a soft, thick piece of cotton cord into and between the glasses of saturated salt solution, as shown in Figure 10–12. Tie each end of the cord

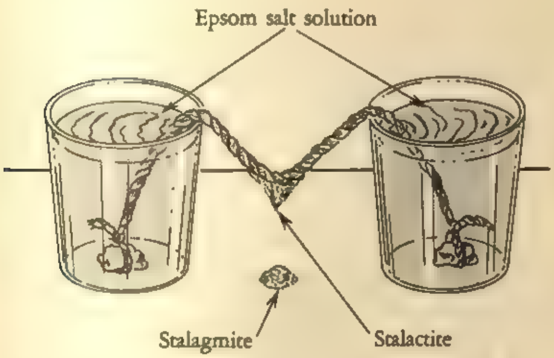


FIGURE 10–12.
FORMING A STALACTITE AND STALAGMITE.

around a small stone or iron washer to prevent the ends of the string from floating on top of the water. In a day or so a "stalactite" and "stalagmite" will form as the water drops from the string, evaporates, and leaves the salt behind. Real stalactites and stalagmites are formed from calcium carbonate that had been dissolved in groundwater containing carbon dioxide.

15. *Running water erodes the earth's surface* · After a heavy rain examine the muddy rivulets of water on the school grounds, carrying away the soil that has been worn away. Streams and rivers will show the same effect, but on a larger scale.

16. *Ocean waves erode the shore* · Observe the ocean waves pounding against the shore, especially on a windy day or after there has been a violent storm. These waves, carrying pieces of rock, will eventually wear the rock down to boulders, then to pebbles, and finally to sand. The waves will also carry these materials out to sea.

17. *Snow changes to ice under pressure* · When the air is below freezing outside, make a snowball out of snow by compressing it firmly with your hands and then set the snowball aside for a few minutes. The pressure will change the snow from fluffy, flaky crystals to grains of ice, just as the pressure of huge piles of snow change the snow at the bottom to granular neve.

18. *Glaciers wear away the earth's surface* · Put gravel, pebbles, and small rocks into a shallow pie tin, barely cover them with water, and place the tin overnight in the freezing compartment of a refrigerator. Remove the frozen mixture the next day and push it across the bare ground. The rocks in the mixture will scratch and gouge the ground and carry some of the earth with it. Allow the ice to melt on the gouged earth; note how "lakes" are formed as the melted water fills up some of the hollows in the earth.

19. *Wind erodes the earth's surface* · Cut out a piece of white paper so that it just fits the bottom of a deep cake tin. Place the paper in the tin and weigh it down with one or two pieces of metal and then put the tin outside on the windowsill. After a day or so note the sediment that the wind has carried and deposited on the paper. An electric fan blowing against a pile of sand will show how the wind originally obtained the sediment.

SOIL

1. *How soil is formed* · Repeat as many pertinent learning activities listed in the previous section, "Forces That Wear Away the Earth's Surface," as you consider necessary to show how weathering forms soil.

2. *Examine topsoil and subsoil* · Collect a sample of topsoil from a flower or vegetable bed. At the same time collect a sample of subsoil after you have dug 1½ to 2 feet into the earth. Compare both kinds of soil for quantities

of humus and pebbles or stones. While keeping all other conditions the same, plant a seed in topsoil and in subsoil, and see which kind of soil produces the sturdier plant.

3. *Bedrock* · Look for areas where the soil has been completely worn away and the solid bedrock can be seen.

4. *Kinds of soil* · Have the children look for and bring in samples of gravel soil, clay soil, sandy soil, and loam. Examine small amounts of the different kinds of soil carefully with and without a magnifying glass.

5. *Composition of soil* · Obtain a tall, cylindrical jar, such as an olive jar, and fill half of it with garden soil. Add water until the jar is almost full and screw the cap on tightly. Shake the jar vigorously for a minute and then set the jar down. The soil will begin to settle in layers. The fine gravel sinks to the bottom immediately, followed by sand, and then by clay and silt. Particles of humus may float on top of the water. The muddy water may take days to become clear because it takes time for the very fine particles of silt and clay to settle.

6. *How fast water goes into the soil* · Cut out both ends of a juice can. Push one end of the can ½ inch into the soil (Figure 10–13). Fill the can to the top with water and see how long it takes the can to become completely empty. Try this experiment in such places as a garden bed, lawn, vacant lot, bare areas of earth, and a highly wooded lot.

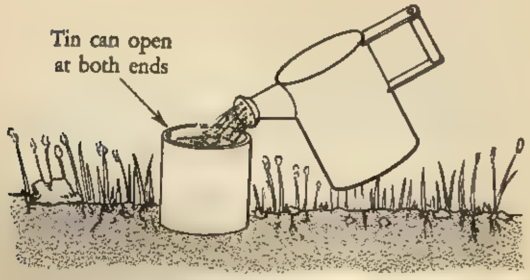


FIGURE 10–13.
MEASURING HOW FAST WATER RUNS INTO THE SOIL.

7. *Soil contains air* · Put some soil into a glass tumbler and slowly pour water over it. Bubbles of air will leave the soil and appear in the water.

8. *Soil contains water* · Place a layer of soil on the bottom of a Pyrex pot. Put the cover on the pot and heat the pot gently on a hot plate. A thin film of water will condense on the sides of the pot and on the underside of the cover as the water in the soil evaporates and then condenses on the cool surfaces.

9. *How soil is eroded* · Repeat as many pertinent learning activities listed in the previous section, "Forces That Wear Away the Earth's Surface," as you consider necessary to show how soil is eroded.

10. *Splash erosion* · Fill the screw cap of a glass jar with soil and tamp down the soil until it is exactly level with the edge of the cap (Figure 10–14). Place the cap of soil in the middle of a large sheet of white paper. Fill a medicine dropper with water and let a few drops of water fall on the soil from a height of 3 to 4 feet. The soil will splash out on the paper. If you put a flower or a small branch, or even a pencil, in the path of the falling drops, the force of the falling water will be broken and the amount of splash erosion will be greatly reduced.

After a rainfall or shower look for splash erosion on the sides of the school buildings or on cellar windows close to the ground. Compare the amount of splash erosion that took place on bare soil areas next to the building and on grassy areas next to the building.

11. *Rill, sheet, and gully erosion* · After a heavy rain look for signs of rill, sheet, and gully erosion on the school grounds or on other areas in your community. Discuss the factors that caused the erosion and the action that could have been taken to prevent the erosion.

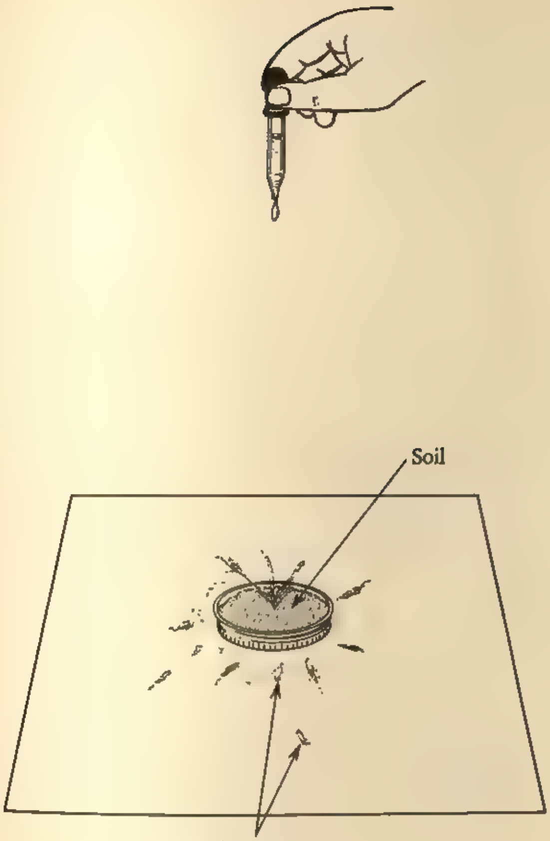


FIGURE 10–14.
SHOWING SPLASH EROSION.

12. *Effects of light and heavy rain on soil* · Fill a flower pot with loose soil and press the soil down until it is level with the edge of the flower pot. Push three bottle caps into the soil so that only their heads show (Figure 10–15). Place the pot in a large basin and sprinkle the soil with water from a watering can. An excellent watering can may be made by punching holes in the metal screw cap of a glass jar. First sprinkle lightly to represent a light rain. Some of the soil will be splashed or washed away, leaving part of the bottle caps exposed. Now sprinkle for some time to represent a heavy rain. Enough unprotected soil will be splashed or washed away to leave the bottle caps completely exposed, with columns of soil remaining under the protecting bottle caps.

13. *Loose soil erodes more than packed soil* · Obtain or construct two wooden boxes, open at one end, about 30 inches long, 9 inches wide, and 6 inches deep. Tack fine wire mesh or screen over the open end of each trough and seal the inside joints and fittings with putty to make the boxes water tight. Fill both boxes with soil, one loosely packed and the other firmly packed. By using pieces of lumber, tilt the boxes so that they both slope at the same angle (Figure 10–16). The lower ends of the boxes should overhang so that runoff water from each box can fall freely into a large, shallow cake tin below the box. (It is advisable to conduct this learning activity outdoors, if possible.) Make two watering cans from glass jars with metal screw caps, as described in Learning Activity 12 above. Now pour the same amount of water in each watering can, and water each box at the same time. The box with the loose soil will lose its soil more quickly, and in greater amounts.

14. *The steeper the slope, the greater the erosion* · By using the same boxes and materials described in Learning Activity 13, fill both boxes with loose soil. Adjust one box with additional lumber so that it tilts more sharply than the other box. Water both boxes with equal amounts of water. The box with the

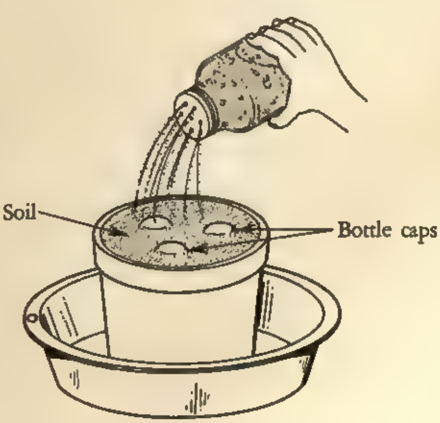


FIGURE 10–15.
HOW LIGHT AND HEAVY RAIN AFFECT EROSION OF THE SOIL.

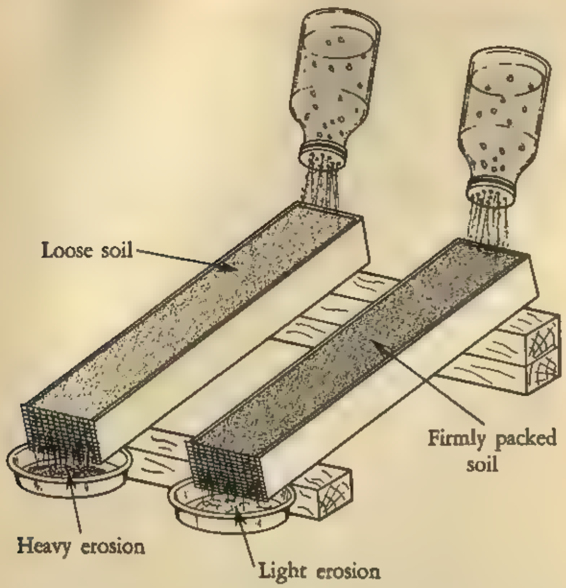


FIGURE 10–16.
SOIL ERODES MORE QUICKLY WHEN LOOSE THAN WHEN FIRMLY PACKED.

steeper slope will lose its soil more quickly, and in greater amounts.

15. *Contour plowing reduces erosion* · By using the same boxes and materials described in Learning Activity 13 above, fill both boxes with loose soil and have them slope at the same angle. With the blunt end of a pencil make long, vertical furrows in the soil of one box and semicircular furrows in the soil of the other box (Figure 10–17). Water both boxes with equal amounts of water. The soil that has been contoured will be washed away more slowly, and in smaller amounts.

16. *Terracing reduces erosion* · Repeat Learning Activity 13 above, but this time work with the soil in one box until you have made a series of terraces. When you water both boxes with equal amounts of water, the terraced soil will be washed away more slowly, and in smaller amounts.

17. *Vegetation reduces erosion* · Repeat Learning Activity 13 above, but this time replace some of the soil in one box with soil that has grass growing in it. When you water both boxes with equal amounts of water, the soil with the vegetation will be washed away more slowly, and in smaller amounts.

18. *Strip cropping and shelter belts reduce erosion* · Collect and show pictures of strip cropping and of shelter belts. Discuss the conditions under which each of these methods operates best and how each condition serves to prevent or slow down erosion.

19. *Collect samples of fertilizers* · Collect small amounts of natural and synthetic fertilizers in small bottles with screw caps. Find out what necessary elements or minerals are contained in each fertilizer and then label each bottle, giving the name of the fertilizer, its constituents, and the percentage if possible.

20. *Discuss crop rotation* · Find out the different kinds of crops that farmers grow in a crop rotation program, together with the sequence of the crops and the reason for using this sequence.

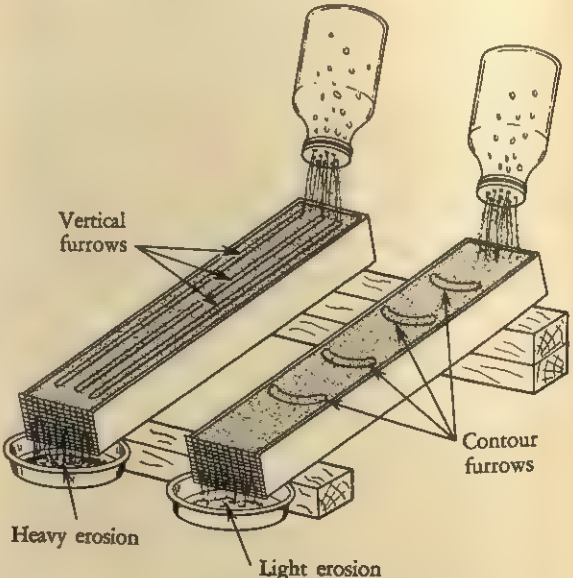


FIGURE 10–17.
CONTOURING THE SOIL REDUCES EROSION.

21. *Examine the roots of legumes* · Dig up a leguminous plant, such as clover, cow peas, soy beans, or alfalfa. Try to collect the roots as intact as possible. Wash the soil carefully and gently from the roots. Examine the nodules, or little white bumps, on the roots. These nodules contain nitrogen-fixing bacteria.

22. *Test soil for acidity and alkalinity* · Moisten the soil and press a pinch of it against litmus paper. Acid soil will turn blue litmus paper red, and alkaline soil will turn red litmus paper blue. If strongly acid or alkaline soil is unavailable, soil can be made acid by adding a few drops of vinegar or made alkaline by adding a few drops of limewater. This procedure also illustrates how soil may either be "sweetened" or made more acid.

HISTORY OF THE EARTH

1. *Collect and observe fossils* · If your school is in an area where fossil rocks are quite common, go fossil hunting. You will need a knapsack, old newspapers for wrapping up specimens, a geologist's hammer or a bricklayer's adz (which is much less expensive than the hammer), a large chisel, and a small chisel. Examine the specimens carefully and consult a good handbook on fossils for identifying them.

If you live in an area where fossils are not available, buy a collection from a natural history museum or scientific supply house. You may want to take the children to a natural history museum or show them pictures of fossils instead.

2. *Examine soft coal for fossils* · Imprints of fern leaves are quite common in soft coal. Collect pieces of soft coal, tap them with a hammer to separate them into layers, and examine the surfaces for leaf imprints and other signs of plants. Discuss how the imprints were formed.

3. *Examine petrified wood* · Many children collect or obtain specimens of petrified wood when they are away on vacation. These specimens are usually well polished. Have the class examine the petrified wood and learn how it was formed.

4. *Make a leaf imprint* · Obtain a pie tin and coat the bottom and sides of the tin with a thin layer of Vaseline. Cover a leaf with Vaseline and place it on the bottom of the pie tin (Figure 10–18). Prepare a mixture of plaster of

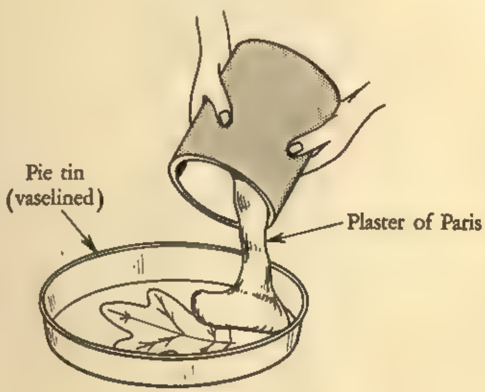


FIGURE 10–18.
A PLASTER OF PARIS LEAF IMPRINT.

Paris in a large tin can by adding water to the plaster of Paris according to instructions on the package. Stir the mixture gently with a flat stick until it is smooth and has the consistency of pancake batter. Now pour the plaster of Paris slowly and gently into the pie tin and over the leaf until you have a layer ½ inch thick. Let the plaster of Paris set for 30 minutes and then remove the cast carefully. Wash the Vaseline off with soap and warm water the next day after the cast has become very hard. Dry the cast with a soft cloth.

Repeat this activity, using a small seashell such as a clam or oyster shell. The cast you obtain will be a negative cast with a hollow imprint of the shell. To make a positive cast with a raised imprint, cover the negative cast with a thin coat of Vaseline. Coat one side of a strip of smooth cardboard, 3 inches high, with Vaseline, and wrap the cardboard around the cast, holding it firmly in place with a strong

rubber band (Figure 10–19). Pour more plaster of Paris over the negative cast until you have a layer at least 1 inch thick. Let the plaster of Paris set for 1 hour. Now remove the cardboard and, inserting a knife gently between the positive and negative coat, separate the two casts. Smooth the sides with sandpaper. The next day wash off the Vaseline with soap and warm water. If you wish, you may preserve the cast by giving it a coat of shellac.

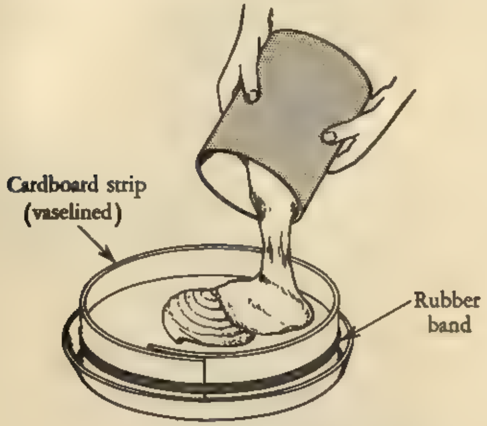


FIGURE 10–19.
MAKING A NEGATIVE AND POSITIVE CAST OF AN IMPRINT.

5. *Make a carbon imprint of a leaf* · Coat a leaf with a very thin layer of Vaseline, making sure to coat the side of the leaf where the veins are raised. Place the leaf, vaselined side up, on a piece of cardboard or some layers of newspaper. Place a sheet of carbon paper, carbon side down, on the leaf. Cover the carbon paper with a sheet of white paper and rub the side of a round pencil back and forth many times on the white paper. The leaf will now be coated with carbon. Now place the leaf, carbon side down, on a fresh piece of white paper, cover the leaf with a second sheet of white paper, and rub the pencil back and forth on this second sheet several times. Remove the top sheet and the leaf. The bottom sheet will have a carbon imprint of the leaf, showing the size, shape, and vein formation. Point out that you made an artificial coating of carbon on the leaf. What actually happens in nature is that the leaf itself carbonizes and forms an imprint on the top and underside of the rock.

6. *Show how plants may be preserved* · Obtain some very fine aquarium or sea sand. If sand is unavailable, borax or baking soda may be used. Cover the bottom of a small, rather deep cardboard box with a layer of 2 inches of sand. Place a fresh flower on the sand and then very gently sprinkle more sand over the flower until you have covered the flower with a layer of sand 3 to 4 inches thick. Let the box stand for a month and then carefully remove the flower from the sand, brushing off the parts with a fine brush, if necessary, to remove any sand grains that cling to the flower. The flower will look as if it has just been cut. Point out that in nature sometimes living things are buried in sand or volcanic ash and thus preserved.

7. *Have a fossil exhibit* · Show actual fossils, with identification labels or cards, accompanied by drawings or pictures of what the living plants and animals actually looked like.

8. *Set up a dinosaur display* · Models of dinosaurs may be purchased from the New York and Chicago Museums of Natural History, and also from certain scientific supply houses. Place cards in front of each dinosaur, giving pertinent information about the dinosaur.

9. *Life in the geologic eras* · Collect pictures of plants and animals that lived in the different geologic eras. Murals or dioramas may be substituted instead.

BIBLIOGRAPHY FOR "THE EARTH"

BARNETT, LINCOLN. *The World We Live In.* New York: Simon & Schuster, 1956. 216 pp.

CHAPMAN, SYDNEY. *IGY: Year of Discovery.* Ann Arbor: U. of Mich., 1959. 111 pp.

CLEMONS, ELIZABETH. *Rocks and the World Around You.* New York: Coward, 1960. 109 pp.

CROSBY, PHOEBE. *Junior Science Book of Rock Collecting.* Scarsdale, N.Y.: Garrard, 1962. 64 pp.

FENTON, CARROLL LANE. *Life Long Ago, the Story of Fossils.* New York: Day, 1937. 287 pp.

FENTON, CARROLL LANE, and MILDRED ADAMS FENTON. *Riches from the Earth.* New York: Day, 1953. 159 pp.

———. *The Rock Book.* New York: Doubleday, 1940. 375 pp.

GATES, RICHARD. *The True Book of Conservation.* Chicago: Childrens, 1959.

GOETZ, DELIA. *Deserts.* New York: Morrow, 1956. 64 pp.

———. *Mountains.* New York: Morrow, 1962. 64 pp.

HARLAND, W. B. *The Earth: Rocks, Minerals, and Fossils.* New York: Watts, 1960. 255 pp.

IRVING, ROBERT (pseud. of Irving Adler). *Rocks and Minerals and the Story They Tell.* New York: Knopf, 1956. 175 pp.

———. *Volcanoes and Earthquakes.* New York: Knopf, 1962. 123 pp.

LAUBER, PATRICIA. *All About the Ice Age.* New York: Random, 1959. 152 pp.

MARCUS, REBECCA. *The First Book of Glaciers.* New York: Watts, 1962. 68 pp.

PARKER, BERTHA M. *The Earth's Changing Surface.* New York: Harper, 1958. 36 pp.

———. *The Earth a Great Storehouse.* New York: Harper, 1959. 36 pp.

———. *Pebbles and Sea Shells.* New York: Harper, 1959. 36 pp.

———. *Soil.* New York: Harper, 1955. 36 pp.

———. *Stories Read from Rocks.* New York: Harper, 1958. 36 pp.

PETERSEN, KAI. *Prehistoric Life on Earth.* New York: Dutton, 1961. 163 pp.

PODENDORFF, ILLA. *The True Book of Pebbles and Shells.* Chicago: Childrens, 1954. 47 pp.

———. *The True Book of Rocks and Minerals.* Chicago: Childrens, 1958. 48 pp.

POSELL, ELSA. *The True Book of Deserts.* Chicago: Childrens, 1958. 47 pp.

POUGH, FREDERICK H. *All About Volcanoes and Earthquakes.* New York: Random, 1953. 150 pp.

REED, W. MAXWELL. *The Earth for Sam.* New York: Harcourt, 1960. 236 pp.

SELSAM, MILLICENT E. *Birth of an Island.* New York: Harper, 1959. 48 pp.

SHUTTLESWORTH, DOROTHY. *The Story of Rocks.* New York: Doubleday, 1956. 56 pp.

SMITH, FRANCES C. *The First Book of Conservation.* New York: Watts, 1954. 69 pp.

STERLING, DOROTHY. *The Story of Caves.* New York: Doubleday, 1956. 121 pp.

SUTTON, FELIX. *The How and Why Wonder Book of Our Earth.* New York: Grosset, 1960. 48 pp.

SYROCKI, B. JOHN. *What Is a Rock?* Chicago: Benefic, 1959. 48 pp.

———. *What Is Soil?* Chicago: Benefic, 1961, 48 pp.

WHITE, ANNE TERRY. *Rocks All Around Us.* New York: Random, 1959. 84 pp.

WILLIAMS, LOU. *Rocks and Minerals.* Chicago: Follett, 1962. 32 pp.

WILLIAMS-ELLIS, AMABEL. *Man and the Good Earth.* New York: Putnam, 1959. 64 pp.

WYLER, ROSE, and GERALD AMES. *The Story of the Ice Age.* New York: Harper, 1956. 81 pp.

ZIM, HERBERT S. *Diamonds.* New York: Morrow, 1959. 64 pp.

———. *What's Inside the Earth?* New York: Morrow, 1953. 32 pp.

ZIM, HERBERT S., and PAUL R. SHAFFER. *Rocks and Minerals.* New York: Simon & Schuster, 1957. 160 pp.

CHAPTER

Water, Weather, *and* Climate 11

WATER

I. The Water Table

A. When water falls to the earth as rain or other forms of precipitation, some of the water sinks into the earth.

B. The water sinks deeper into the earth until it reaches the solid rock underneath the soil.

C. This solid rock may be porous or nonporous.

1. Porous rock, usually called **permeable** rock, is either loose (like gravel) or has spaces in it (like sandstone), and it allows the water to enter and pass through it.
2. Nonporous rock, usually called **impermeable** rock, is firm and solid (like granite) so that it stops the water from sinking any deeper.

D. The water will continue to sink deeper into the earth until it is stopped by a layer of nonporous or impermeable rock.

E. The soil and rock above this nonporous layer then become soaked or saturated with water, which is called **groundwater.**

F. The upper level of the groundwater in the soaked soil and rock is called the **water table.**

G. The height of this water table depends upon how much rain has fallen recently, how porous the soil and rock are, and how far down the porous layer goes until it meets a layer of nonporous rock that will not let the water sink any deeper.

H. Also, during dry weather the level of the water table sinks, and during rainy weather the level rises.

I. As a rule, the level of the water table follows the general contour of the land, sloping where the surface of the land slopes, and rising where the surface rises.

J. The groundwater can flow through a porous layer of soil and rock, and thus makes it possible for water to enter the ground at one place and to appear in another place later.

K. Whenever the land surface dips below the water table, the groundwater flows out to the surface of the land, forming a spring, joining with a river, or helping to feed a pond or lake.

II. Wells

A. A well is a hole that is dug or drilled deep enough into the ground to reach the water table.

1. Water then flows into the hole, filling

it with water and forming a well.

2. When water is taken out of the well, it is replaced by the water that is flowing underground.

B. A well must be dug deep enough so that, when the level of the water table drops during dry weather, the well will not run dry.

C. An artesian well is a well that is sunk deep into the earth's surface.

1. In artesian wells the water is obtained from a layer of porous rock, called an aquifer, which is sandwiched between two layers of nonporous rock.
2. This layer of porous rock originally began at the earth's surface and then slanted downward into the earth.
3. Water entering this layer of porous rock can only travel through this porous layer, and it cannot move up or down through the nonporous layers of rock above and below it.
4. When a well is drilled deep enough to reach this porous layer, the water in it rises up again, either to the land surface or to just below the surface, depending upon the contour of the land.
5. The water rises because the water behind it is at a higher level, and it is exerting pressure upon it.
6. The water in the artesian well is under pressure in exactly the same way as the water at the bottom of a long, slanting pipe would be under pressure.
7. The water from artesian wells is usually very pure because it comes straight up the walls of the well and does not dissolve any minerals in other layers of rocks on its way up.

III. Springs

A. When the water table meets the earth's surface, a spring is formed.

B. Springs may also form on hillsides where the water table cuts across the earth's surface.

C. Spring water usually has minerals dissolved in it.

D. Spring water that comes from deep below the earth's surface may often have so many minerals dissolved in it that the water is not suitable for drinking.

E. Hot springs form when the groundwater is heated because of volcanic activity going on below the earth's surface.

1. The water is either heated by contact with the hot, melted rock, called magma, or by mixing with steam and hot gases that are escaping from the magma.
2. Hot springs are common in regions where volcanic activity is going on because the heated rocks are very near the earth's surface in these areas.
3. Because hot water dissolves minerals better than cold water, most hot springs have a high mineral content.

IV. Lakes

A. Lakes are large bodies of water found on many parts of the earth's surface.

B. Lakes usually are made up of a depression, called a basin, that is filled with water.

1. Some lake basins were formed by faulting, in which layers of rock inside the earth slipped over other layers of rock and were pushed up to form a hollow in the earth's surface.
2. Some basins were formed when forces within the earth that were sideways acted on layers of rock and pushed them into wavelike folds with a crest and a hollow trough.
3. Glaciers often gouged out deep hollows as they moved across the earth's surface, leaving these hollows to fill with water as the glaciers later retreated.
4. Some basins were formed when lava from a volcano built a dam across a valley.
5. Lakes were often formed from rivers when trees, brush, and other debris

clogged up the river, making the river back up to form a lake.

C. Lakes obtain their water in many ways.
  1. Rain and other forms of precipitation fall directly into the lake.
  2. Rain that falls on land around the lake runs off into the lake.
  3. Rivers flow into the lake.
  4. When the water table is above the surface of the lake basin, groundwater flows into the lake in the form of a spring.

D. Lakes do not stay on earth as long as hills or mountains do.
  1. Some lakes become filled up with sediment carried by streams that fill the lake.
  2. Sometimes plants growing at the edge of the lake advance farther and farther into the lake until the lake becomes filled up and disappears.
  3. Some lakes disappear because the springs in their basins, or the rivers that feed the lakes, dry up and disappear.

E. A swamp is a lake basin that is partly or completely filled with live plants, dead plants, sediment, and water.
  1. Some swamps are just beginning to become lakes, whereas others are slowly becoming dry land.
  2. When swamps are drained, they make very fertile farm land.

V. Impurities in Water

A. As rain begins to fall, it is very pure.

B. However, as it falls through the air, it dissolves some of the gases in the air and also picks up bits of dust and bacteria that are floating in the air.

C. As soon as the rain reaches the ground, it begins to pick up many impurities.
  1. Many kinds of minerals dissolve in the water.
  2. Some sand, silt, mud, and other sediments are not dissolved, but they remain suspended in the water as very fine particles.
  3. The water also comes in contact with all kinds of bacteria that are found in plant and animal wastes.

D. Some of the impurities in water are harmless, whereas others can be very harmful.
  1. Small amounts of minerals and gases in water make the water taste better because the water would taste "flat" without them.
  2. Many bacteria are very harmful, and they must be removed or killed before the water is suitable for drinking.

VI. Purification of Water

A. In the home, harmful bacteria in the water can be killed by boiling, and suspended material and gases that give the water a bad taste can be removed by passing the water through charcoal.

B. In the laboratory, water can be purified by **distillation.**
  1. In distillation the water is boiled, and the water vapor that forms is led through a tube that is surrounded by cold water, which condenses the water vapor back into water again.
  2. The heat drives off the gases dissolved in the water before the water begins to boil and is changed into water vapor.
  3. The hot, boiling water kills the bacteria, which are left behind when the water is changed into water vapor.
  4. Minerals and suspended materials are also left behind when the water is changed into water vapor.

C. Cities go through several steps when they purify water for use in the home.

D. First, the water is run into large basins, where the suspended particles of sediment are allowed to settle to the bottom.
  1. Because the very tiny particles settle very slowly, two chemicals—alum and lime—are added to the water.
  2. In the water these chemicals form a jellylike material, to which the very fine particles of sediment stick.
  3. The jellylike material becomes heavier

when the tiny particles are stuck to it, and it settles to the bottom.

4. Some of the bacteria in the water are also trapped by the material, and they are removed when the material settles.

E. The water is then passed to another basin that has layers of sand and gravel in it.

1. The water passes through these layers, which remove the rest of the suspended particles together with more of the bacteria.
2. Sometimes a layer of charcoal is placed between the sand and gravel to remove coloring matter and bad-tasting gases in the water.

F. Now the water is treated to remove the remaining bacteria.

1. One way to remove the bacteria is to spray the water into the air, which allows the oxygen in the air to kill the bacteria and at the same time puts air into the water to give it a better taste.
2. If there is a large amount of bacteria present, the water may also be treated with chlorine, which kills all the bacteria but gives the water a bad taste.

G. Some cities now add fluorides to the water because fluorides help prevent or reduce tooth decay.

VII. Hard Water

A. Water that has certain minerals dissolved in it, in the form of calcium and magnesium salts, is called **hard water**.

B. Hard water is difficult to use for washing purposes because it will not form a lather with soap; instead, it forms a scum.

1. The scum is the product formed when the dissolved calcium and magnesium salts react with the soap.
2. We call it hard water because it is "hard" to make a lather or wash with this water.

C. Hard water is also objectionable because it leaves mineral deposits inside steam furnaces, hot-water heaters, hot-water pipes, and tea and coffee pots.

D. Hard water can be "softened" in different ways.

E. One way to soften hard water is to add such chemicals as ammonia, washing soda, borax, or trisodium phosphate, which remove the calcium and magnesium from the water.

1. A second way is to use a chemical called **zeolite.**
2. Zeolite removes the calcium and magnesium when hard water is passed through it, and it replaces these minerals with sodium, which does not affect soap.
3. When zeolite is used up and does not work any longer, it can be restored by soaking it overnight in a strong salt-water solution.

F. A third way to soften hard water is to use certain resins, which are able to remove calcium and magnesium from the water.

G. Rainwater that has not touched the ground is very soft water, and it is excellent for washing purposes.

H. Today, **detergents** are often used instead of soap.

1. Detergents are not soaps, but they are made up of chemicals that have a cleaning action just like soap.
2. The chemicals in detergents are not affected by the calcium and magnesium in hard water so that they lather easily in hard water and do not form a scum.
3. Detergents come either in solid or in liquid form.

VIII. Water Exerts Pressure

A. Water has weight, and it exerts a pressure because of its weight.

B. At any given point in the water, the water will exert a downward, upward, and sideways pressure.

1. At this particular point the pressure is the same in all directions.
2. At a deeper point in the water, the pressure will be greater, but this new and greater pressure will again be the same in all directions.

C. When water is placed in a container, its pressure is greatest at the bottom.
   1. The shape of the container does not affect the water pressure on the bottom, but the height of the container does.
   2. The higher the container, the deeper the water, and the greater the water pressure will be at the bottom.
   3. The pressure of the water on the bottom is greater than the pressure of the water on the sides of the container.

D. When water is in a closed container, any pressure on the water will be sent or transmitted in all directions through the container.
   1. This pressure occurs because the molecules of water are so close together that the pressure is passed unchanged from molecule to molecule.
   2. Special machines, called **hydraulic machines**, make use of this special behavior of water in a closed container, being able to send a small force elsewhere and, at the same time, change the small force into a much larger force.
   3. Common hydraulic machines include the **hydraulic press** for baling cotton, the **hydraulic lift** for raising automobiles, and the **hydraulic brakes** in a car or truck.

IX. Moving Water Can Do Work

A. When water moves from a higher level to a lower level, because of the earth's pull of gravity on the water, it has a great deal of energy.
   1. This energy of motion, which moving water has, is called **kinetic energy.**
   2. Because of kinetic energy, the water can exert a great deal of pressure and force.
   3. The faster the water moves, the greater kinetic energy it will have.

B. Moving water can be used to turn water wheels.
   1. Some water wheels are used to grind grain or run machines in factories.
   2. Other special water wheels, called **turbines,** are used to run large electric generators that produce electricity.

X. Steam Can Do Work

A. When water is heated to a high enough temperature, it will boil, changing from a liquid into a gas called steam.

B. When water changes into steam, it expands tremendously and can exert a great deal of pressure and force.

C. Steam can be used to run machines and engines.

D. Steam can also be used to turn large turbines, which will then run giant electric generators.

XI. Sinking and Floating

A. When a body is placed in water, two forces act on the body.

B. One force is the earth's pull of gravity, which pulls downward on the body.
   1. The weight of the body determines the amount of downward force acting on the body.
   2. The heavier the body, the greater the earth's pull of gravity on it, and the larger the downward force will be.

C. The second force is the upward force of the water that has been displaced, or pushed out of the way.
   1. The size of the body determines the amount of upward force the displaced water can have.
   2. The larger the body, the more water it can displace, and the greater the upward force will be.

D. A small, heavy body will usually sink in water.
   1. Because it is small, the body will displace a small amount of water, and a small, upward force will act on the body.
   2. Because the body is heavy, the downward force due to the pull of gravity will be great.
   3. Because the downward force acting on the body is greater than the upward

force acting on the body, the body will sink.

E. A large, light body will usually float in water.
  1. Because it is large, the body will displace a large amount of water, and a large, upward force will act on the body.
  2. Because the body is light, the downward force due to the pull of gravity will be small.
  3. Because the upward force acting on the body is greater than the downward force acting on the body, the body will float.

F. Although steel is quite heavy, a steel ship can float.
  1. The steel is spread out over a large area to form a hollow shell so that it will displace a large amount of water and a large, upward force will act on the steel.
  2. The downward force, caused by the combined weight of steel, air, equipment, passengers, and cargo, is still less than the upward force caused by the displaced water, so the steel ship floats.
  3. When a steel ship is set afloat, it sinks until it displaces just enough water to create an upward force greater than the downward force produced by the ship's weight.
  4. When the ship is loaded, it sinks deeper until enough water is displaced to produce an additional upward force to support the weight of the cargo.

G. A submarine floats for the same reason that a steel ship floats.
  1. The submarine is able to sink because it has tanks that let in water and make the submarine heavy enough (or increase the downward force enough) to sink.
  2. When the water is pumped out of the tanks, the submarine becomes lighter and rises to the surface.

H. A body floats easier in salt water than in fresh water.
  1. The same downward force of gravity acts on the body, whether the body is in salt water or fresh water.
  2. However, salt water is heavier than fresh water because it has more minerals dissolved in it.
  3. As a result, displaced salt water has a greater upward force than displaced fresh water.
  4. If a ship sails from fresh water into salt water, it rises further out of the water because the salt water has a greater upward force than the fresh water.
  5. If a ship sails from salt water into fresh water, it sinks further into the water because the fresh water has a smaller upward force than the salt water.

XII. Conservation of Water

A. Every year there is a greater need for more water.
  1. Today, each person in the United States uses about 15,000 gallons of water a year for drinking, washing, laundry, cooking, heating, and air-conditioning purposes.
  2. Industry uses large amounts of water; scientists estimate that industry uses 160,000 gallons of water a year for each person living in the United States.
  3. Agriculture also uses large amounts of water to irrigate the land.

B. As the population in the United States grows, the need for water will soon become greater than the supply.

C. We must take steps to conserve all water that is available.
  1. We should avoid needless use and waste of water.
  2. Soil and forest conservation helps prevent water from running off quickly before it can be used.
  3. The building of dams holds back river water that is rushing to the sea.
  4. Scientists are looking for a way to change seawater into usable fresh water.

D. Our water is also being polluted.
  1. Factories are pouring into rivers large amounts of waste materials that pollute the water.

2. Wastes and sewage from homes in many cities are also dumped into rivers without being treated first so that the water will not be polluted.
3. This pollution of water means that other cities and factories, which are located downstream, must purify the water before they can use it.
4. Sometimes the waste materials accumulate or are so strong that, even after all regular methods of purifying water are used, the water is still unfit to use.

E. This pollution of the water cuts down even more the amount of usable water that we need.

F. Pollution of water can be prevented.
1. Cities and factories should treat wastes and sewage instead of sending them downstream.
2. Modern sewage disposal plants should be established, which separate the waste materials from the water and thus make it possible for the water to be used again.

THE OCEANS

I. The Oceans of the Earth

A. Although we usually think of the oceans as separate bodies of water, we should keep in mind that all the oceans are part of one great sea.
1. This sea covers almost 75 percent of the earth.
2. There are no natural divisions that separate one ocean from the other.

B. There are five great oceans on earth: the Pacific, Atlantic, Indian, Arctic, and Antarctic Oceans.

C. The Pacific Ocean is the largest ocean.
1. It includes about three eighths of the total area of the sea.
2. It is the deepest ocean, with an average depth of about 14,000 feet.

D. The Atlantic Ocean is the next largest ocean.
1. Its area is about one fourth of the total area of the sea.
2. Its average depth is about 13,000 feet.

E. The Indian Ocean has an area that is about one eighth of the total area of the sea.

F. The Arctic Ocean is really a northern extension of the Atlantic Ocean.
1. It is a small ocean, with about one thirtieth of the sea's area.
2. It is almost completely covered with ice to a depth of 8 to 10 feet.

G. The Antarctic Ocean is at the south in the region that surrounds the antarctic continent.

II. The Ocean Floor

A. The lower parts of the earth's surface, where the oceans are located, are called **ocean basins.**

B. These ocean basins are the true surface of the earth whereas the continents are really huge islands that were raised above the ocean basins by forces acting inside the earth.

C. The depth of the ocean varies.
1. Over the **continental shelf,** which is really the edge of a continent under water, the ocean is very shallow and is rarely more than 500 to 600 feet deep.
2. Beyond the continental shelf, however, the ocean becomes much deeper very quickly, as the edge of the continent drops off sharply to the bottom of the ocean, forming a slope called the **continental slope.**
3. The deep **ocean floor** begins at the end of the continental slope.
4. The average depth of the ocean floor is

2½ miles, although in some places the ocean is roughly 7 miles deep.

D. The ocean floor is not smooth, but it is made up of many mountains and valleys.

E. In the Atlantic Ocean there is a tremendous mountain chain, called the **Mid-Atlantic Ridge**, on the ocean floor.

1. This mountain chain is about 200 miles wide, 10,000 feet high, and stretches along the entire Atlantic Ocean to the southern tip of Africa.
2. Here the mountain chain joins with a similar mountain chain that runs through the Indian Ocean.
3. This Indian Ocean chain then joins with many chains of mountains that stretch across the Pacific Ocean.
4. The tops of these Mid-Atlantic mountains are higher than those found on the continents; yet most of them are at least a mile below the surface of the ocean.
5. The Azores in the North Atlantic and Ascension Island in the South Atlantic are tops of the very high mountains in this chain.

F. These mountains are believed to be formed from volcanic activity that took place long ago.

G. Volcanic activity has also been responsible for forming mountains in other parts of the ocean floor.

1. The islands in the oceans are the tops of these mountains extending above the surface of the ocean.
2. The Aleutian Islands, West Indies, and South Sea Islands are tops of mountains on the ocean floor.

H. Near these islands are huge **trenches** and **troughs**, which are very deep.

1. These trenches and troughs may be as long as 1000 miles and as wide as 100 miles.
2. They have been formed by cracks in the earth's crust, called **faults**, where the volcanic action that formed these islands took place.
3. The deepest parts of the ocean are found in these trenches and troughs.

I. In the continental slopes are deep canyons, some of which are larger than the Grand Canyon, which are believed to have been carved out of the slope by underwater ocean currents.

J. The entire ocean floor is covered with a large layer of sediment.

1. The continental shelf is covered with gravel, sand, clay, and shells.
2. The ocean floor itself is covered with a soft, fine ooze or mud, made up of volcanic dust and the remains of tiny sea plants and animals.

III. Exploring the Ocean

A. The science of the study of the oceans is called **oceanography.**

B. Oceanographers use many devices and instruments to study the ocean.

C. The **water-sampling bottle** is a device that collects water at different depths of the ocean.

D. The **deep-sea thermometer** measures the temperature of the ocean at different depths.

E. The **bottom sampler** is a device that collects samples of material at the bottom of the ocean.

F. The **current meter** is an instrument that measures the speed and direction of the ocean currents.

G. The **deep-sea camera** can take pictures of sea life in the deep parts of the ocean and of the materials on the ocean floor.

H. The **sonic-depth recorder** measures the depth of the ocean.

1. On the ship the recorder sends sound waves toward the bottom of the ocean.
2. The sound waves strike the bottom of the ocean and are reflected back to the ship.
3. The recorder records the time required for the sound to travel to the bottom of the ocean and to be reflected back to the ship.
4. By knowing the time, as well as the speed of sound in water, we can easily

calculate the distance to the bottom of the ocean.

I. Oceanographers also use a small underwater vessel, called a **bathyscaphe,** which allows men to explore the ocean and its bottom.

IV. Seawater

A. The composition of the seawater today is not the same as the water in the oceans long ago.
  1. At first the waters of the oceans were fresh, and they had no salts in them.
  2. As rain fell on the land, many minerals were dissolved and carried to the oceans by the rivers and streams.
  3. Each year the oceans become more and more salty.

B. Today, every 100 pounds of seawater contains about 3½ pounds of dissolved minerals.
  1. About three fourths of this mineral material is common salt, or sodium chloride.
  2. The rest of the minerals are salts of magnesium, calcium, and potassium.

C. Some of the dissolved minerals can be very valuable to man.
  1. Each cubic mile of seawater has about 4 million tons of magnesium, which is used in planes and for other purposes, and almost all the world's supply of magnesium is obtained from seawater.
  2. Bromine is also obtained from seawater, and it is used in making high-test gasoline and photographic film.
  3. Common salt, or sodium chloride, is obtained from seawater.
  4. Although each cubic mile of seawater has about 90 million dollars worth of gold in it, scientists say that it would cost more than 90 million dollars to recover this amount of gold.

D. The temperature of the seawater varies.
  1. Seawater is warmest at its surface.
  2. The warmest surface water is found in oceans near the equator.
  3. In the tropics, the surface of the water is about 70 degrees Fahrenheit, although in the Persian Gulf the temperature has been as high as 96 degrees Fahrenheit.
  4. In the polar regions, the average temperature of the surface of the water is about 28 degrees Fahrenheit, which is the freezing point of salt water.
  5. Most parts of the sea have surface temperatures between those of the tropical oceans and the polar oceans, depending upon their location and upon weather conditions.
  6. Deeper down in the ocean, the temperature of the water becomes colder, and, even at the equator, the temperature of the ocean may be 35 to 40 degrees Fahrenheit.

E. There are two kinds of ice found floating in the sea: **icebergs** and **floes.**

F. Icebergs are large blocks of glaciers that break off and float in the sea.
  1. Icebergs are freshwater ice.
  2. Icebergs are dangerous to ships because about nine tenths of an iceberg is below the surface of the water, and the part below the surface is often spread out far in all directions.
  3. The larger icebergs in the northern hemisphere may be ½ to 1 mile long, with 300 feet of ice showing above the water.
  4. The icebergs that break off the Antarctic glaciers are huge, and they may be more than 40 miles long.

G. Floes are large pieces of frozen seawater that come down from the Arctic Ocean.
  1. In the Arctic Ocean, the temperature is cold enough for the surface water to freeze so that the Arctic Ocean is always covered with an ice pack about 10 to 15 feet thick.
  2. During the summer, some of this ice pack melts and breaks up, sending large pieces of ice floating southward.
  3. These floes are different from icebergs in that they are smaller, have a flat shape, and are saltwater ice.

V. Waves

A. Ocean waves are made by winds.
  1. As the wind blows across the water, there is friction between the moving air and the surface of the water.
  2. This friction makes the water rise and fall in a regular rhythmic movement, called a **wave.**

B. A wave has two parts.
  1. The highest point to which the water rises is called the **crest** of the wave.
  2. The lowest point to which the water falls is called the **trough** of the wave.

C. The height of a wave is the vertical distance between its crest and its trough.

D. The length of a wave is the horizontal distance from one crest to another, or from one trough to another.

E. The stronger the wind and the greater the distance over which the wind blows, the greater the waves will be.

F. During a storm, waves may be more than 60 feet high and 500 feet long, and they may travel through the water at speeds as high as 60 miles an hour.

G. On very windy days, waves may have a foamy white top, called **white caps.**
  1. White caps occur when the strong winds push the water off the tops of the waves.
  2. White caps can be formed close to shore or far out at sea.

H. When waves reach the shore, **breakers** are formed.
  1. A wave approaching the shore travels smoothly until its trough hits the bottom of the seashore.
  2. The trough of the wave is slowed down as it rubs against the bottom of the seashore.
  3. At the same time the water in the wave piles up, and the wave becomes higher and higher.
  4. Finally, the crest of the wave falls forward, and the wave breaks to form a breaker.
  5. At beaches where the seashore is steep, breakers form very close to shore, and they do not last very long.
  6. At beaches where the seashore is very shallow, breakers form far out, and they can last for as long as a mile.

I. When a wave strikes the beach, the water immediately begins to move back down the beach and along the ocean bottom as an **undertow.**
  1. The returning undertow moves underneath the waves that are coming in.
  2. The stronger the waves, the more water they throw up on the beach, and the stronger the returning undertows become.
  3. Undertows carry away sand from the beach to the deeper sea.

J. Giant waves, called **tsunamis,** are produced by earthquakes or volcanic explosions at the bottom of the ocean.
  1. Tsunamis are often mistakenly called "tidal" waves.
  2. Tsunamis are different from regular waves because they can be more than 100 miles long and can travel at speeds as high as 500 miles an hour.
  3. In midocean these tsunamis are only a few feet high; however, close to shore they may become more than 100 feet high and cause a great deal of damage.

VI. Surface Ocean Currents

A. The surface waters of the oceans are constantly moving in the form of currents.

B. The movement of these surface waters is mainly caused by the force of the winds blowing on the water.

C. If the earth were completely covered with water and the winds always blew with the same force and from the same direction, the surface currents of the sea would move in a great circle around the earth.

D. However, there are many factors that affect the direction these currents follow.
  1. The winds on earth actually blow with different force and from different directions.

2. Because the earth rotates, the waters in the northern hemisphere move to the right, and the waters in the southern hemisphere move to the left.
3. The outlines of the earth's continents make the currents turn and change direction.
4. The depth and shape of the ocean floor may also affect the direction of the currents.

E. Currents that flow away from the equator are warm currents, and currents that flow toward the equator are cold currents.

VII. The Equatorial Currents

A. In the oceans that lie along the equator, there are powerful currents just above and below the equator.

B. These currents move toward the west, driven by the steady winds that are present in these regions.

C. If there were no continents, these currents would move in a continuous circle around the earth.

D. However, the continents make these currents turn to the north or the south, and they even make the currents turn back on themselves as well.

E. The current flowing just above the equator is called the **North Equatorial Current,** and the current flowing just below the equator is called the **South Equatorial Current.**

VIII. The North Atlantic Currents

A. The North Equatorial Current moves westward to the West Indies.

B. At the West Indies this current branches.
1. One branch moves north along the east coast of the United States as the **Gulf Stream.**
2. The other branch goes into and around the Gulf of Mexico, where it becomes enlarged and warmer, and then it passes through the Straits of Florida and flows north, rejoining the first branch at Cape Hatteras and becoming part of the Gulf Stream.

C. The Gulf Stream is one of the strongest water currents on earth, moving about 3 or 4 miles an hour in a path that is about 100 miles wide.

D. Because of the earth's rotation, the Gulf Stream moves to the right, northeast toward Europe.

E. When the Gulf Stream reaches the North Atlantic Ocean, it branches into three weaker currents.
1. One branch, the **Labrador Current,** eventually turns around and carries colder water southward to the northeast coast of the United States as far as Cape Cod, where it then sinks below the surface.
2. The second branch goes directly to Europe, where it warms the shores of Iceland, the British Isles, Norway, and Sweden.
3. The third branch turns south, as the **Canary Current,** and returns to the North Equatorial Current.

F. In this way there is a complete circle of current in the north Atlantic Ocean.

G. In the center of this circle is a very large, quiet area of water, called the **Sargasso Sea,** where great masses of sargassum seaweed accumulate.

IX. The South Atlantic Currents

A. The South Atlantic Currents are just like the North Atlantic Currents, but they flow in the opposite direction.

B. The South Equatorial Current moves westward, to the northern part of South America, where it turns south.

C. It then moves along the South American coast as the **Brazil Current.**

D. Then it moves east as the **South Atlantic Current** to Africa, where it moves north as the **Benguela Current,** and finally it returns to the South Equatorial Current.

X. The North Pacific Currents

A. In the Pacific Area, the North Equatorial Current moves westward to the Philippines, where most of it turns northward as the **Japan Current** (the equivalent of the Atlantic Ocean's Gulf Stream).
B. The warm Japan Current then turns to the northeast as the **North Pacific Current.**
C. The North Pacific Current approaches the Pacific coast, and it divides into two branches.
  1. One branch, the **Alaska Current,** flows northward and warms the southern coast of Alaska.
  2. The other branch, the **California Current,** flows southward, carrying cooler waters down the west coast of the United States, and it rejoins the North Equatorial Current off the coast of Mexico.

XI. The South Pacific Currents

A. The South Equatorial Current of the Pacific moves westward across the Pacific Ocean.
B. Because of the many islands in the South Pacific, it is rather difficult to follow the direction of this current as it nears Asia and is turned to the south.
C. These islands weaken the current by dividing it into a number of smaller currents that go off in different directions.
D. The only strong current in the South Pacific is the **Peru Current,** which carries cold water from the south polar region to the coast of South America and then rejoins the South Equatorial Current of the Pacific.

XII. The Antarctic Current

A. The **Antarctic Current** is formed in the southernmost parts of the Atlantic and the Pacific Oceans.
B. Winds that are blowing to the west produce this Antarctic Current.
C. Because there are no land masses in this area, this current completely circles the Antarctic region of the earth.

XIII. Deep-Sea Currents

A. In addition to surface currents that are driven by the wind, there are also powerful currents that flow deep below the surface of the sea.
B. Some deep currents are caused by the slow movement of cold water from the polar regions to the equator.
  1. Since cold water is heavier than warm water, the cold waters around the polar regions sink and travel along the ocean bottom to the equator.
  2. In 1959, which was the International Geophysical Year (IGY), scientists found a deep current 9000 feet below the Gulf Stream, going in the opposite direction with a speed of about 8 miles a day.
  3. Other deep currents, also traveling in opposite directions from the surface currents, have been discovered in the South Atlantic Ocean and also in the Pacific Ocean.
C. Some deep currents are caused by a difference in the amount of salt in the seawater.
  1. The more salt in the seawater, the heavier the water will be.
  2. Since the Mediterranean Sea is shallow compared to the large oceans, a large amount of its water is exposed at its surface.
  3. As a result, the waters of the Mediterranean Sea evaporate more quickly than the waters of the larger Atlantic Ocean; consequently, its waters become more salty and heavier.
  4. At Gibraltar, where the Atlantic Ocean and Mediterranean Sea meet, there is a strong, deep current of saltier and heavier water that runs along the sea bottom past Gibraltar and into the Atlantic Ocean.
D. Scientists still know very little about deep-sea currents because the currents are so

deep and circulate so slowly that they are hard to follow and study.

XIV. LIFE IN THE OCEAN

A. The ocean water has all the necessary conditions to support a wide variety of plant and animal life.
  1. It has a tremendous amount of minerals and other chemicals dissolved in it.
  2. It also has a large amount of air dissolved in it.

B. Most plants and animals that live in the ocean are found either near the shore or in the surface waters.

C. At the bottom there can be found such living things as seaweeds, grasses, sponges, oysters, clams, crabs, and lobsters.

D. The ocean also has in it very tiny plants and animals, called **plankton**, which are the basic food for sea life.
  1. Plankton grow in tremendous numbers in the upper layers of the ocean, where the sun can reach them.
  2. All forms of sea life either feed directly on plankton or eat animals that feed upon plankton.

E. In the middle and bottom parts of the ocean there are also living things, but they do not look at all like the living things found near the surface.

F. Tiny sea animals, called **corals**, affect shorelines in warm waters.
  1. These sea animals live in colonies in warm, shallow water that must be 68 degrees Fahrenheit or higher.
  2. The animals swim around freely when they are young, but, when they become older, they become fastened to the rocky sea floor.
  3. Now the corals depend upon the waves and currents to bring food to them.
  4. The corals also take lime from the seawater to make the shells in which they live.
  5. When the corals die, they leave their shells behind, and new colonies of corals grow on top of these shells.
  6. Eventually, the shells accumulate until they form a **coral reef**, which is separated from the mainland by a broad lagoon of calm water.
  7. Sometimes, when there is a sunken volcanic cone not too far below the surface of the water, the corals form in a narrow, circular ring, called an **atoll.**

XV. ECONOMIC IMPORTANCE OF OCEANS

A. Oceans are like huge highways, which ships use to bring food and supplies to all parts of the world.

B. The ocean supplies a large amount of the food we eat.

C. The ocean has chemicals in it, which industries take out and use.

D. The ocean makes it possible for us to grow things on land.
  1. Water evaporates in tremendous amounts from the surface of the oceans, forming water vapor that goes into the air.
  2. The air then moves across the land, and eventually the water vapor condenses out as rain and other forms of precipitation, providing water for the soil.

E. Because our demand for water eventually will become greater than the supply, scientists are already looking for inexpensive ways of changing salt seawater into the fresh water that we can use.

WINDS

I. The Earth and Its Atmosphere Are Heated by the Sun

A. The radiant energy from the sun passes through the air without heating it very much.

B. Most of the sun's radiant energy strikes the earth's surface, which absorbs this energy and changes it into heat.

C. The heated earth's surface then warms the air above it in two ways.

1. The warm earth radiates some of its heat energy back into the air, which absorbs much of this heat energy and becomes warmer.
2. Although air is a poor conductor of heat, some of the earth's heat is conducted into the air just above the earth.

D. At the same time, as the sun's radiant energy passes through the air, a small amount of this energy will be absorbed by the air nearest the earth and be changed into heat.

E. Every day the air goes through a cycle of heating and cooling.

1. When the sun shines upon the earth, the air becomes warmer as the heated earth radiates heat energy.
2. At night the earth cools off, and the air becomes cooler.
3. The air becomes much warmer in the summer, when the days are longer, than in the winter, when the nights are longer.
4. Cloudy nights will be warmer than clear nights because the clouds act as a blanket to reflect and absorb the radiant energy given off by the earth, and in this way they keep the heat within the air next to the earth.

II. The Earth Is Heated Unequally

A. The shape of the earth produces unequal heating.

1. The earth's surface is curved so that the sun's rays strike different parts of the earth at different angles.
2. At the equator, the sun's rays strike the earth's surface directly or at right angles.
3. Away from the equator, the sun's rays strike the earth's surface at a slant.
4. The closer we get to the polar regions, the more the earth is curved, and the greater is the slant of the sun's rays striking the earth's surface.
5. Direct rays are warmer than slanted rays because with direct rays the sun's energy is concentrated over a smaller area of the earth's surface, whereas with slanted rays the same amount of energy is now spread out over a large area, making the energy less concentrated.
6. Because the earth's surface that receives direct rays of the sun becomes warmer than the surface that receives slanted rays, the air above this warmer surface becomes warmer as well.
7. When one part of the earth has summer, this part is tilted so that the sun's rays shine directly on its surface, and this part of the earth becomes warmer.
8. When the same part of the earth has winter, this part is now tilted so that the sun's rays shine at a slant on its surface, and this part of the earth now becomes cooler.

B. The different surfaces of the earth are heated unequally.

1. Some surfaces of the earth absorb and radiate heat faster than others.
2. Dark and rough land surfaces, such as rocks and soil, absorb heat quickly and radiate it just as quickly.
3. On the other hand, bodies of water have clear, smooth surfaces, and they absorb and radiate heat more slowly.
4. As a result, when the sun shines directly upon land and water surfaces, the land surfaces become warmer than water sur-

faces, and the air above the land surfaces becomes warmer as well.

III. The Unequal Heating of the Earth Produces Winds

A. Wind is the movement of air set up by the unequal heating of the earth's surface by the sun.
B. This movement of air is in the form of a **convection current.**
  1. When air next to the earth is heated, it expands and becomes lighter.
  2. This warmer, lighter air is pushed up by the colder, heavier air that surrounds it.
  3. The colder, heavier air now is heated and becomes lighter, being pushed up in turn by more cold, heavy air that surrounds it.
  4. This process continues until there is a steady flow of air, called a convection current, with warm air rising and cold air falling.
C. Cold air is heavier than warm air, and so it exerts a greater pressure than warm air.
D. Winds are formed when cold air from high-pressure areas moves to low-pressure areas where the air is warmer.

IV. Wind Belts of the Earth

A. There is a constant movement of air over the entire earth in the form of **wind belts.**
B. If the earth did not rotate on its axis, the movement of the air over the earth would be quite simple.
  1. At the equator the heated air would rise and flow toward the north and south poles.
  2. At the north and south poles the colder air would move toward the equator.
C. However, because the earth does rotate, the movement of air over the earth becomes more complicated.
  1. The winds in the northern hemisphere are deflected to the right, and the winds in the southern hemisphere are deflected to the left.
  2. As a result, a series of wind belts is produced around the earth, with the winds in each belt moving in a definite direction.
D. Because the sun's rays shine differently on the northern and southern hemispheres in the summer and winter, the wind belts shift with the seasons.

V. The Doldrums

A. The **doldrums** is an area of low pressure at the equator.
B. Most of the air movement in the doldrums is upward, as the heated air rises.
C. As a result, there are mostly calms in the doldrums, with occasional light breezes.

VI. The Horse Latitudes

A. The heated air above the equator rises and moves toward the north and south poles, cooling as it moves high into the air.
B. At about one third of the distance from the equator to the poles (30 degrees latitude), the air has cooled enough to sink down toward the earth's surface again.
C. This belt of descending, high-pressure air is called the **horse latitudes.**
D. The air is still warm, but not as warm as the air in the doldrums.
E. There are also mostly calms in the horse latitudes, with occasional light, changeable winds.

VII. The Trade Winds

A. The air sinking down at the horse latitudes forms two wind belts: one flowing back to the equator and the other flowing toward the poles.
B. The winds flowing back to the equator are called the **trade winds.**
C. Because of the earth's rotation, in the northern hemisphere the trade winds are deflected or turned to the right and become the **northeast trade winds.**

D. In the southern hemisphere the trade winds are deflected to the left and become the **southeast trade winds.**

E. The trade winds blow very steadily with respect to direction and speed.

VIII. The Prevailing Westerlies

A. The winds that flow from the horse latitudes toward the poles are called the **prevailing westerlies.**

B. Because of the earth's rotation, in the northern hemisphere the prevailing westerlies are deflected to the right and become the **southwesterlies.**

C. In the southern hemisphere the prevailing westerlies are deflected to the left and become the **northwesterlies.**

D. The prevailing westerlies are not as steady as the trade winds, and they will vary both in direction and speed.

IX. The Subpolar Lows

A. At a little more than two thirds of the distance from the equator to the poles (65 degrees latitude), there is a second belt of low-pressure area, called the **subpolar lows.**

B. At this point, the warmer air that is still moving toward the poles is pushed up by the cold air moving down from the poles toward the equator.

C. The upward movement of this warm air produces an area of low pressure.

X. The Polar Easterlies

A. At the poles, masses of cold air move down toward the equator.

B. They move to the right in the northern hemisphere to become the **polar northeasterlies,** and to the left in the southern hemisphere to become the **polar southeasterlies.**

C. These winds have the same direction as the trade winds, but they are very cold and violent.

XI. The Jet Stream

A. In the northern hemisphere, there is a narrow band of high-speed winds, called the **jet stream.**
   1. These winds are located in the belt of the prevailing westerlies, but they are 6 to 9 miles above the surface of the earth and travel at speeds as high as 400 miles an hour.
   2. They move eastward around the earth, but their direction often varies.

B. The position and speed of the jet stream varies with the seasons.
   1. It moves closer to the north pole in the summer, and it shifts farther south in the winter.
   2. It is about 7 to 9 miles high in the summer, and 4 to 6 miles high in the winter.
   3. Its winds move faster in the summer than in the winter.

C. In 1959, during the International Geophysical Year (IGY), scientists discovered three more jet streams.
   1. There is one in the southern hemisphere that is exactly like the stream in the northern hemisphere.
   2. There is one in the lower stratosphere of the Arctic Circle.
   3. There is one in the lower stratosphere of the Antarctic Circle.

D. In the winter, jet planes take advantage of the jet stream, using it as a strong tailwind to cut down flying time.

XII. Monsoons

A. A **monsoon** is a seasonal wind that changes its direction in the summer and in the winter.

B. This wind is produced by the difference in heating between continents and oceans during the summer and winter.
   1. In the summer, the land is heated more than the ocean so that the cooler air over the ocean moves in across the land.
   2. In the winter, the land becomes colder than the ocean so that the cooler air

over the land moves out toward the ocean.

C. The best example of a monsoon is found in India.

D. In the summer, the Indian Ocean is cooler than the hot land.
   1. The air above the hot land becomes hot and light, forming a low-pressure area, and the cooler, moist air from the Indian Ocean blows across the land.
   2. This **summer monsoon,** also called a **wet monsoon,** brings India its rainy season from May through October.

E. In the winter, northern India becomes much colder than the Indian Ocean.
   1. The air above the cold land becomes cold and heavy, forming a high-pressure area, and the cold, dry air blows from the land to the Indian Ocean.
   2. This **winter monsoon,** also called a **dry monsoon,** brings dry weather to India from November through April.

F. Australia, Spain, and Portugal also have monsoons.

XIII. Land and Sea Breezes

A. Land and sea breezes are rather like daily monsoons.

B. They are winds at the seashore that blow in one direction in the daytime and in the opposite direction at night.

C. During the day, the land and sea receive the same amount of heat from the sun, but the land heats up more quickly and becomes hotter than the sea.
   1. The air over the land becomes warmer and lighter than the air over the sea.
   2. The warmer air over the land is forced upward by the colder air coming in from over the sea to produce a **sea breeze.**
   3. At the seashore a sea breeze usually begins before noon and dies down at sunset.

D. At night the land cools more quickly than the water, and the air over the land becomes colder and heavier than the air over the water.
   1. The colder, heavier land air moves out to sea, forming a **land breeze.**
   2. Land breezes blow during the night and die down at sunrise.
   3. Land breezes are weaker than sea breezes.

E. Land and sea breezes can also be formed at large lakes.

XIV. Mountain and Valley Breezes

A. Mountain and valley breezes are also a kind of daily monsoon.

B. During the day, the sunny, exposed mountain heats up more quickly than the sheltered, shady valley.
   1. The air over the mountain becomes warmer and lighter than the air in the valley.
   2. A cool **valley breeze** then blows up the mountain, as it pushes the warmer, lighter mountain air up and away.

C. At night the mountain cools more quickly than the valley.
   1. The air over the mountain now becomes colder than the air in the valley.
   2. A cool **mountain breeze** then blows down the mountain into the valley, pushing the warmer, lighter valley air up and away.

D. The narrower the valley, the stronger the mountain and valley breezes will be.

E. Because a valley breeze has to travel uphill, its speed is not as great as a mountain breeze.

WATER IN THE AIR

I. Evaporation

A. When water changes from a liquid into an invisible gas, called **water vapor**, this change is called **evaporation.**

B. Evaporation always takes place at the surface of the water.

C. Evaporation takes place because of molecular motion within the water.

1. Water is made up of tiny molecules that are constantly moving.
2. Some of these molecules have more energy and move faster than others.
3. The faster moving molecules near the surface of the water leave the surface and go off into the air, becoming molecules of water vapor.

D. Some solids, like moth balls, can evaporate directly as a solid without first becoming a liquid.

II. Factors Affecting Evaporation

A. There are several factors that affect the speed of evaporation.

B. Heat will make water evaporate more quickly.

1. Heat makes the molecules move faster.
2. As a result, more molecules can leave the water at one time.

C. The larger the surface, the more quickly evaporation will take place because more molecules can leave the water at one time.

D. The amount of water already in the air affects the speed of evaporation.

1. If the air already contains a lot of water vapor, there is less room in the air for more molecules of water vapor to enter, and the speed of evaporation is slow.
2. If the air contains only a little water vapor, there is plenty of room in the air for more molecules to enter, and evaporation takes place more quickly.

E. Wind helps water evaporate more quickly.

1. As the molecules leave the water and become water vapor, the air above the water eventually becomes filled, or saturated, with water vapor.
2. This saturation slows down evaporation because there is no more room in the air for more molecules of water vapor to enter.
3. Wind blows away the air that is saturated with water vapor, and provides fresh air that can hold a fresh supply of water vapor.

F. The lower the air pressure above the surface of the water, the faster evaporation takes place.

1. Lower air pressure means that the air is not pressing down as hard on the surface of the water.
2. This lower air pressure makes it easier for the molecules to leave the water and go into the air as water vapor.

G. Warm, dry air can hold more water vapor than cold, moist air; consequently, the warmer and drier the air above the water, the faster the water evaporates.

H. Liquids other than water also evaporate, and some liquids evaporate faster than others because their molecules are moving faster, from the beginning, at the same temperature.

III. Evaporation Is a Cooling Process

A. When a liquid evaporates, it takes in, or absorbs, heat.

B. The liquid gets this heat from materials around it.

C. When a drop of liquid is placed on a person's skin, the liquid begins to evaporate.

1. In this case the evaporating liquid gets its heat from the skin, leaving the skin cooler.
2. The quicker the liquid evaporates, the more heat it needs, and the cooler the skin becomes.
3. This is the reason why the evaporation

of perspiration, or water, on the skin cools the body.

D. When a liquid evaporates, the liquid itself becomes cooler.
   1. The faster moving molecules in the liquid have a higher temperature than the slower moving molecules.
   2. When the faster moving molecules leave a liquid and become a vapor, the cooler, slower moving molecules are left behind, making the liquid cooler.

IV. Humidity

A. **Humidity** refers to the water vapor in the air.

B. The **absolute humidity** is the actual amount of water vapor present in the air at a certain temperature.

C. The **relative humidity** is the ratio between the actual amount of water vapor in the air (absolute humidity) at a certain temperature and the maximum amount of water vapor the air can hold at that temperature.

D. The relative humidity is usually multiplied by 100 to give the result in percentages.

E. When the air contains as much water vapor as it can hold at a certain temperature, the air is said to be **saturated**, and the relative humidity is 100 percent.

V. Condensation

A. When water vapor changes into a liquid, the change is called **condensation**.

B. Condensation takes place because of a change in molecular motion of the molecules of water vapor in the air.
   1. When air containing water vapor is cooled, the water-vapor molecules move more slowly and come closer together.
   2. If the air is cooled enough, the water-vapor molecules come close enough together to become water again.

C. Condensation also takes place because air contracts, or becomes smaller, when cooled.
   1. As air containing water vapor is cooled, the air will keep on contracting until it is saturated with water vapor and can hold no more.
   2. Any further cooling will make the air contract even more, and cause some of the water vapor to condense from the air.

D. The temperature below which air must be cooled for condensation to take place is called the **dew point.**

E. The same factors that affect the speed of evaporation also affect the speed of condensation, but in reverse, so that a condition that speeds up evaporation slows down condensation, and vice-versa.

VI. Dew and Frost

A. Dew and frost are forms of condensation that take place on surfaces at or near the earth at night.

B. During the night, the earth's surface and solid objects on it give up their heat rather quickly and become cool.

C. The air coming in contact with these surfaces also is cooled.

D. If the air is cooled below its dew point, the water vapor in the air condenses on these surfaces as water droplets, called **dew.**

E. If the dew point is below freezing (32 degrees Fahrenheit), the water vapor condenses directly as crystals of ice, called **frost.**

F. Frost is not frozen dew.

G. Dew and frost condense on any surface that has a temperature lower than the dew point of the air that touches this surface.

H. Dew and frost form more easily on a clear night, when the surfaces can radiate their heat away more quickly through the air, whereas clouds act like a blanket to prevent the heat from radiating away.

I. Dew and frost form more easily on a calm

night because winds blow the air around and prevent the air next to the earth from getting cold enough to cause condensation.

VII. Fog

A. When a sizable layer of air next to the earth's surface is cooled below its dew point, the water vapor in this layer condenses into tiny water droplets to form a fog.
   1. The water droplets are heavier than air, but they are so small and fall so slowly that the slightest air movement is enough to keep them floating in the air.
   2. A fog is really a cloud on the ground.

B. A **ground fog** is formed under exactly the same conditions as dew and frost are formed.
   1. Ground fogs often form in valleys, which fill with cold, heavy air.
   2. In the morning the sun warms the air, which expands and can now hold more water vapor, and the water droplets in the fog evaporate and the fog disappears.

C. An **advection fog** is formed when warm, moist air from one region blows over a cool surface.
   1. In the Grand Banks of Newfoundland, fogs are very common because the warm, moist air from the Gulf Stream blows constantly over the cold Labrador Current.
   2. Advection fogs are quite common along the seacoast when warm, moist air from the sea blows over the cooler land.

VIII. Clouds

A. Clouds, like fogs, are formed when a mass of air is cooled.
   1. When warm air containing water vapor rises high in the air, it becomes colder.
   2. The warm, rising air reaches levels where the air pressure is less, and the air expands.
   3. When air expands by itself, it uses up some of its heat energy to make it expand, and the air becomes colder.
   4. If the air is cooled below its dew point, the water vapor in the air condenses as tiny droplets of water to form a cloud.
   5. The water vapor usually condenses around tiny bits of dust or other particles in the air.
   6. If the air is below freezing (32 degrees Fahrenheit), the water vapor condenses directly as tiny crystals of ice.
   7. Just as with the fog, the droplets of water or ice crystals in the cloud are heavier than air, but they are so small and fall so slowly that the slightest air movement is enough to keep them floating in the air.

B. A cloud on earth would look like a fog, and a fog high in the air would look like a cloud.

C. The shapes of the clouds are determined by how they are formed.
   1. If the movement of the cooling air is vertical, the clouds form in large, billowy masses.
   2. If the movement of the cooling air is horizontal, the clouds form in layers.

D. There are three basic types of clouds: **cirrus, cumulus,** and **stratus** clouds.

E. Cirrus (meaning "curl") clouds are the highest clouds in the sky.
   1. They look like thin wisps of curls or like thin feathers.
   2. They can be from 4 to 8 miles up in the sky.
   3. Because they are so high in the sky, they are always made up of tiny ice crystals.

F. Cumulus (meaning "heap") clouds look like large fluffs of cotton or wool.
   1. They are flat on the bottom, but they can pile up very high.
   2. They most often form in the afternoon, and they usually disappear toward evening.
   3. They are usually associated with fair weather.
   4. On hot summer days, cumulus clouds may grow very large and black, causing

thunderstorms with heavy rain and sometimes hail.

G. Stratus (meaning "layer") clouds are made up of low layers of clouds.
  1. They are the nearest clouds to the earth.
  2. They usually cover the whole sky and blot out the sun.
  3. They are usually associated with stormy weather.

H. Sometimes a cloud is given two names because it has the characteristics of two different clouds.
  1. **Cirrostratus clouds** are high, thin, feathery layers of ice-crystal clouds that often produce a halo or "ring" around the moon or sun, indicating the coming rain or snow.
  2. **Stratocumulus clouds** are layers of cumulus clouds that cover the whole sky, especially in winter.
  3. **Cirrocumulus clouds** are a large group of small, round, fluffy clouds that are made up of ice crystals.

I. Scientists also add prefixes to clouds, which help them describe the clouds more accurately.
  1. Such prefixes include *alto* (meaning "high"), *nimbus* or *nimbo* (meaning "rain"), and *fracto* (meaning "broken").
  2. **Altostratus clouds** are high stratus clouds.
  3. **Nimbostratus clouds** are rain clouds.
  4. **Cumulonimbus clouds** are thundershower clouds, also called **thunderheads.**
  5. **Fractocumulus clouds** are cumulus clouds that have been broken up into smaller masses.

IX. Precipitation

A. **Precipitation** refers to all forms of moisture that fall from the atmosphere.
  1. **Rain, drizzle, sleet, snow,** and **hail** are forms of precipitation because they fall from the atmosphere.
  2. Dew, frost, fog, and clouds are not forms of precipitation, according to scientists that study the weather, but are considered forms of condensation instead.

B. Rain is the water that falls from a cloud.
  1. The droplets of water in a cloud are so small that the slightest air movement is enough to keep them floating in the air.
  2. These droplets come together and form larger drops, which in turn come together to form even larger drops.
  3. When the drops of water are large and heavy enough, they fall to the earth as rain.

C. Drizzle is the only other form of precipitation that falls as a liquid.
  1. Drizzle is made up of very fine cloud (or fog) droplets that fall very slowly.
  2. Ordinarily, these water droplets would stay in the cloud or fog, but sometimes the air is so still that they fall to earth.

D. Snow is the most common form of solid precipitation.
  1. Snow forms from water vapor that condenses when the temperature of the air is below freezing.
  2. The water vapor condenses directly into ice crystals, or snow.
  3. Snow, therefore, is frozen water vapor, and not frozen rain.
  4. Every snow crystal has six sides to it, but no two snowflakes are exactly alike.
  5. When the air near the ground is cold, the snowflakes fall separately.
  6. When the air near the ground is warmer, the snowflakes melt together to form large clots of wet, sticky snow.

E. Sleet is frozen rain, and it is usually formed during the winter when raindrops fall through a below-freezing layer of air that is near the ground.

F. Glaze is a coating of ice that forms when rain freezes after it reaches the ground.
  1. The rain forms a thick coating of ice on streets, trees, telephone and electric wires, and other objects.
  2. When this phenomenon occurs, it is called an ice storm.
  3. The coating of ice often becomes so heavy that it makes bushes and tree branches collapse, breaks telephone and electric

wires, and makes traveling on highways dangerous or impossible.

G. Hail is formed mostly in the summer during a thunderstorm, when there are strong upward currents of air within the thundercloud.
1. These currents carry the raindrops high into a layer of below-freezing air.
2. The raindrops freeze and become pellets of ice.
3. These pellets of ice then fall into warmer air, where they pick up another coating of water.
4. Then the pellets, now coated with water, are blown up again into the colder air, where the coating of water freezes to form a second layer of ice.
5. This process is repeated until the pellets of ice, now called **hailstones,** become too heavy for the upward air currents to lift, and the hailstones fall to earth.
6. The hailstone is formed somewhat like an onion, with an ice pellet as its center and many layers of ice around this center.
7. Each layer shows one complete movement up into cold air and back down again into warmer air.
8. The more violent the thunderstorm, the more times the hailstones move up and down between the layers of cold and warm air, and the larger the hailstones become.
9. When hailstones are large, they can cause great damage to crops and can even hurt small animals.

X. The Water Cycle

A. All the water on earth is constantly evaporating to form water vapor.
1. This evaporation takes place from the surfaces of the oceans, lakes, ponds, reservoirs, and rivers.
2. Evaporation also takes place from plants and the soil.

B. This water vapor is constantly condensing back into water again.
1. On or near the ground the water vapor condenses as dew, frost, and fog.
2. High in the air the water vapor condenses as clouds, rain, snow, sleet, or hail.

C. This process of evaporation and condensation goes on in a continuous cycle, called **the water cycle.**

D. The oceans are the basic source of all the water that the land surfaces receive because practically all the water that falls on the land surfaces eventually goes back to the oceans in some way.
1. Some of the water runs off into rivers and streams, and it is carried to the oceans.
2. Some of the water sinks into the ground, where it flows underground through roundabout paths either directly to the sea or to streams and lakes on the earth's surface.
3. Most of the water that falls on land surfaces evaporates directly into the air from bodies of water on land, from plants, and from the soil.
4. This evaporated water is carried by air currents to the oceans, where it falls as rain, snow, sleet, or hail.
5. The water then evaporates from the surfaces of the oceans, and the moist air is carried by air currents across the land, where it meets conditions that make the water vapor condense back to water again.

WEATHER CHANGES

I. Causes of Weather

A. When describing the weather at a certain time and place, the weatherman usually lists the conditions of the air at that time and place.

B. These conditions include the temperature of the air, the air pressure, the amount of moisture in the air (humidity), and the direction and speed of the wind.

C. When predicting the weather, the weatherman looks at the kinds of air masses that are moving across the earth.

D. These air masses are responsible for changes in the weather.

II. Air Masses

A. An **air mass** is a huge body of air that may cover millions of square miles of the earth's surface and may be thousands of miles wide and many miles high.

B. In any air mass the temperature and humidity are about the same throughout.

C. Air masses differ greatly from each other, and the weather that an air mass will bring depends mostly on the particular temperature and humidity that it has.

D. An air mass is formed when the atmosphere stays quietly over a certain part of the earth's surface until it picks up the temperature and humidity of that part of the earth's surface.

1. An air mass formed over Canada will be cold and dry.
2. An air mass formed over the Gulf of Mexico will be warm and moist.

E. Air masses are named according to the part of the earth's surface in which they are formed.

1. Those that are formed in the tropics are called **tropical** (T), and are warm.
2. Those that are formed in the polar regions are called **polar** (P), and are cold.
3. Besides the tropical and the polar regions, the air masses come from continents or oceans.
4. Air masses from continents are called **continental** (c), and are dry.
5. Air masses from oceans are called **maritime** (m), and are moist or humid.

F. As a result, there are four possible kinds of air masses.

1. The **continental tropical** (cT) air mass is dry and warm.
2. The **maritime tropical** (mT) air mass is moist and warm.
3. The **continental polar** (cP) air mass is dry and cold.
4. The **maritime polar** (mP) air mass is moist and cold.

G. Once an air mass is formed, it is usually carried to another place by the general movements of the atmosphere.

H. Air masses often change their conditions when they move from one place to another place.

1. A dry air mass can move out over the ocean and become moist.
2. When a cold air mass moves over a warmer surface, the lower part of the air mass becomes warmer and rises, producing clouds and possibly precipitation.
3. A warm air mass can become a cold air mass automatically, just by moving over a part of the earth's surface that is warmer than the air mass.
4. In the same way, a cold air mass can become a warm air mass if it moves over a colder part of the earth's surface.

III. North American Air Masses

A. The air masses that affect the weather in North America come from six different areas.

B. **Polar Canadian** (cP) air masses are formed over north-central Canada.

1. These air masses move in a southeasterly

direction across Canada and northern United States.
2. They are cold and dry.
3. In the winter they bring the cold waves that sweep across the United States and sometimes move as far south as the Gulf coast.
4. In the summer they bring cool, dry weather.

C. **Polar Atlantic** (mP) air masses are formed over the northern Atlantic Ocean.
1. Although they generally move eastward toward Europe, they can also move southward to affect the northeastern part of the United States.
2. They are cold and moist.
3. In the winter they bring cold, cloudy weather and some form of light precipitation.
4. In the summer they bring cool weather with clouds and fogs.

D. **Polar Pacific** (mP) air masses are formed over the northern Pacific Ocean.
1. They usually travel southward along the Pacific coast, but sometimes they move eastward across the United States.
2. They are cool rather than cold, and are very moist.
3. In the winter they bring rain and snow, and in the summer they bring cool, foggy weather.

E. **Tropical continental** (cT) air masses are formed over Mexico and southwest United States.
1. They usually move in a northeasterly direction over the central part of the United States.
2. They are warm and dry.
3. They affect North America only in the summer, and they bring dry, clear, and very hot weather.

F. **Tropical Atlantic** (mT) air masses are formed over the tropical part of the Atlantic Ocean and the Gulf of Mexico.
1. They usually move in a northeast direction over the eastern part of the United States.
2. They are warm and moist.
3. In the winter they bring mild weather, and in the summer they bring hot, humid weather and thunderstorms.

G. **Tropical Pacific** (mT) air masses are formed over the tropical part of the Pacific Ocean.
1. They usually move in a northeasterly direction across the Pacific coast.
2. They are warm and moist.
3. They affect the Pacific coast only in the winter, and they bring cool, foggy weather.

IV. Weather Fronts

A. When two air masses meet, the boundary between them is called a front.
1. Along the front there is almost always some form of precipitation.
2. This precipitation occurs because a very large amount of warm, moist air is rising to great heights along the front, and rising, moist air means precipitation.

B. There are two common kinds of fronts.
1. If warm air is pushing colder air ahead of it, the front is called a warm front.
2. Because masses of warm tropical air usually come from the southwest, warm fronts in the United States generally move toward the northeast.
3. If cold air is pushing warmer air ahead of it, the front is called a cold front.
4. Since masses of cold polar air usually come from the northwest, cold fronts in the United States generally move toward the southeast.

C. In the Temperate Zones of both North and South America, the principal changes in weather are brought about by the passage of warm and cold fronts.

D. When a warm front advances, the warm air moves up over the cold air that is retreating.
1. The slope of the warm front is very gradual, and the warm air may have to travel 500 to 1000 miles to rise 5 miles.
2. When the warm air rises, it becomes cool, and the water vapor in the air

condenses to form large masses of clouds along the entire warm front.

3. Where the level of the warm air is highest, cirrus clouds form.
4. Behind the cirrus clouds are different forms of stratus clouds, each kind floating lower and lower, with nimbostratus or "rain" clouds last and nearest the ground.
5. The rains produced by a warm front cover a wide area, are usually steady, and last until the warm front passes.

E. When a cold front advances, the cold air pushes under the warm air that is retreating, and lifts up this warm air.

1. The cold front moves more quickly than a warm front because the air in the cold front is colder and heavier.
2. Heavy, cold air can push light, warm air out of the way more quickly than light, warm air can push heavy, cold air.
3. As the warm air is lifted up very quickly, it cools, and the water vapor in the air condenses to form different kinds of clouds, especially cumulonimbus (or thundershower) clouds.
4. The rains produced by a cold front cover a smaller area, are rather violent, and last only a short time.
5. Cold front rains come both before and after the cold front passes.

F. A **stationary front** is the boundary line between a cold air mass and a warm air mass when both air masses stop and do not move for several days.

1. When this stoppage occurs, the boundary between the two air masses becomes a slope that is as gentle as that of a warm front.
2. As a result, the weather produced by a stationary front is about the same as that produced by a warm front.

G. Sometimes an **occluded front** is formed when a warm air mass, which lies between two cold air masses, is lifted up by the cold air mass behind it.

1. To create an occluded front, both cold air masses and the warm air mass between them must all be moving in the same direction.
2. Because cold fronts move faster than warm fronts, sometimes the second cold air mass at the rear catches up with the first cold air mass in front, and at the same time lifts the warm air mass completely off the ground.
3. This condition, called an occluded front, brings a combination of warm and cold front weather.
4. Also, as the occluded front passes, there is no change in the temperature of the air because there is only a change from one mass of cold air to another.

V. Lows and Highs

A. The air masses that move across earth differ in air pressure.

1. Cold air masses have higher pressures than warm air masses.
2. This difference occurs because cold air is heavier than warm air, and it can exert more pressure than warm air.

B. An area of low pressure is called a **low**, or a **cyclone**.

1. The lowest air pressure in a low is at its center.
2. As a result, air of higher pressure blows inward toward the center of the low.
3. Because of the earth's rotation, the air in the northern hemisphere is deflected to the right.
4. This deflection makes the air blowing toward the center of the low travel in a circular, counterclockwise direction.
5. Tornadoes, which are small, violent, whirling storms, are often wrongly called cyclones.

C. An area of high pressure is called a **high**, or an **anticyclone**.

1. The highest air pressure in a high is at its center.
2. As a result, air blows outward from the center of the high.
3. Because of the earth's rotation, the air blowing outward from the center of a

high travels in a circular, clockwise direction in the northern hemisphere.

D. Lows, or cyclones, usually bring bad weather.
   1. This weather occurs because the warmer, lighter air in a low-pressure area is pushed up by the colder, heavier air around it.
   2. The warmer, lighter air rises and becomes colder so that clouds and precipitation are formed.
   3. The bad weather caused by lows usually covers a wide area.

E. The lows in the United States start in the northwest, southwest, and southeast.
   1. They move toward the northeast and end in New England, bringing all kinds of weather changes.
   2. They travel about 700 miles a day in the winter, and 500 miles a day in the summer.

F. Highs, or anticyclones, usually bring good weather.
   1. This weather occurs because the colder, heavier air in a high-pressure area is falling toward the earth.
   2. As the air falls, it becomes warmer.
   3. Because warm air can hold more moisture, or water vapor, than cold air, no precipitation takes place and the weather is bright and clear.

G. Highs in the United States can start either in polar or tropical regions.
   1. They also travel eastward across the United States, but more slowly than lows do.
   2. Highs from the polar regions bring extreme cold waves in the winter, and cool, clear weather in the summer.
   3. Highs from the tropical regions bring mild weather in the winter, and hot, dry spells in the summer.

VI. Hurricanes

A. Hurricanes are lows, or cyclones, that form in the tropics over the oceans.
   1. They usually form between June and November.
   2. During these months the tropics receive a tremendous amount of heat energy from the sun.
   3. This heat energy causes vast amounts of ocean water to evaporate, and warm, moist air forms above the surface of the ocean.
   4. Huge amounts of colder, heavier air move in on the warmer, lighter air and push the warmer, lighter air upward.
   5. As a result, a violent, whirling storm is formed.

B. In some ways the hurricane is very much like a low.
   1. The hurricane is also a low-pressure area, but its air pressure is much lower than the low.
   2. The winds in both the hurricane and the low spiral in a counterclockwise direction in the northern hemisphere, and in a counterclockwise direction in the southern hemisphere.
   3. Both the hurricane and the low cause heavy precipitation, but the precipitation is much heavier in the hurricane.
   4. Near the center of the hurricane the rain comes down in torrents.

C. In other ways the hurricane is different from a low.
   1. The hurricane is more intense, and it covers a smaller area, usually 200 to 400 miles in diameter.
   2. The hurricane has no fronts.
   3. In the exact center there is a calm area, called the "eye" of the hurricane, about 12 to 15 miles in diameter, where the sun shines, the sky is clear, and there are almost no winds.
   4. Around the "eye" the winds may whirl at a speed of more than 150 miles an hour.

D. Although the winds in a hurricane blow at a great speed, the hurricane itself moves rather slowly.
   1. In the tropics the hurricane moves

slowly, with a speed of about 10 miles an hour.

2. As the hurricane moves away from the tropics into the area where the prevailing westerlies blow, it moves faster and can reach a speed of 50 miles an hour.
3. In the northern hemisphere the hurricane continues to move in a northeasterly direction, and eventually it moves out to sea and blows itself out.

E. The biggest damage produced by a hurricane is caused by the waves it produces.

1. Along the coast the winds form great waves that cause flooding, especially if the waves come at the same time as the high tides.
2. The force of the winds also causes damage to homes and property.

F. These tropical lows or cyclones are called different names in different parts of the earth.

1. In the West Indies they are called **hurricanes.**
2. In the western Pacific Ocean they are called **typhoons.**
3. In the Indian Ocean they are called **cyclones.**
4. In Australia they are called **willy-willies.**
5. In the Philippine Islands they are called **baguios.**

VII. Tornadoes

A. **Tornadoes** are the smallest, most violent, and most short-lived of all storms.

B. They occur almost exclusively in the United States, chiefly in the Mississippi Valley and the eastern half of the Great Plains.

1. The states where tornadoes commonly form are Iowa, Kansas, Texas, Arkansas, Oklahoma, Mississippi, Illinois, Indiana, and Missouri.
2. However, tornadoes may also occur in any level land area.
3. They are most frequent during the spring and early summer, and they usually occur during the afternoon.
4. There are about 200 tornadoes a year in the United States.

C. Tornadoes are formed under special conditions.

1. Ordinarily cold, heavy air moves under warm, light air.
2. When a tornado is formed, a layer of cold, dry air is pushed over a layer of warm, moist air.
3. The warm, moist air then quickly forces its way in a spiral movement through the layer of cold air.
4. Strong, whirling winds are formed around a center of low pressure, producing a tornado.
5. Tornadoes are also called **twisters.**

D. The tornado looks like a narrow, funnel-shaped, whirling cloud that is very thick and black.

1. The funnel reaches down toward the earth, and its tip touches the earth as it moves along.
2. Sometimes the funnel rises for a while, and then it comes down again a short distance away.
3. The tornado varies in size, and it can have a diameter a few hundred feet to a mile wide.
4. Although the tornado itself moves in a wandering path at a speed of about 25 to 40 miles an hour, the winds spin around like a top and can reach a speed of 500 miles an hour.
5. When a tornado passes a particular point, there is a deafening roar.
6. Usually a tornado is accompanied by lightning, thunder, and heavy rain.
7. The tornado lasts an average of 8 minutes, and it travels about 16 miles.

E. A tornado that passes over a body of water is called a **waterspout.**

1. In a waterspout the bottom part of the funnel is made of spray instead of the dust and other materials found in a tornado over land.
2. The waterspout has very little water in it.
3. Most of the bottom part is a fine mist or

spray with perhaps a few feet of water at the bottom.

F. A tornado can cause a tremendous amount of damage.
1. The strong winds blow away almost everything in their path.
2. The center of the tornado is also very destructive because the air pressure within the funnel is very low.
3. Buildings within the center of the funnel often explode because the normal air pressure inside the building becomes so much greater than the suddenly reduced air pressure outside.
4. For the same reason cars, houses, trees, people, and animals are pushed or "sucked" into this funnel of very low pressure.

VIII. THUNDERSTORMS

A. **Thunderstorms** are strong, local storms that are formed from cumulonimbus clouds.
1. They are accompanied by lightning, thunder, heavy rain, and strong gusts of wind.
2. Sometimes hail falls at the beginning of a thunderstorm.
3. A thunderstorm is short, rarely lasting more than 2 hours, but it is possible to have many thunderstorms in a day.

B. Thunderstorms are formed whenever warm, moist air is pushed upward rapidly, accompanied by equally rapid downdrafts of cool air.

C. An **air-mass thunderstorm,** usually called a **summer thunderstorm,** is formed within an air mass during hot, summer afternoons.
1. It happens when hot, moist air above the earth's surface rises, forming first cumulus and then cumulonimbus clouds.
2. Summer thunderstorms are local storms, and they will form over scattered areas.

D. A **frontal thunderstorm** is formed when a cold front arrives, pushing warmer air ahead of it.
1. This air movement forms a series or long line of thunderstorms, which may be hundreds of miles long and up to 50 miles wide.
2. Frontal thunderstorms can happen at any time of the day or year.

E. **Lightning** is a huge electrical spark produced during thunderstorms.
1. The fast-rising air rubs against the water droplets in the cloud and charges them electrically.
2. The top of the cloud becomes positively charged while the bottom of the cloud becomes negatively charged.
3. Sometimes the force of the fast-rising air is strong enough to rip the cloud in two so that each half has a different electrical charge.
4. When the force of attraction between the positively and negatively charged parts of a cloud becomes great enough, a huge spark of electricity, called lightning, flows from the negatively charged part to the positively charged part.
5. Lightning can flow between the bottom and top of the same cloud, between two clouds of different charges, from a cloud to the earth, and sometimes even from the earth to a cloud.

F. **Thunder** is the sound produced by the rapid heating and expansion of the air through which the lightning passes.
1. The rumbling of thunder is a series of echoes produced when thunder is reflected many times by the clouds.
2. Lightning is seen first and the thunder is heard next.
3. This order happens because lightning travels with the speed of light, which is about 186,000 miles a second, while thunder travels with the speed of sound, which is about ⅕ mile a second.
4. Because it takes the sound of thunder about 5 seconds to travel 1 mile whereas lightning is seen almost instantaneously, we can easily calculate how far away

we are from the lightning of a thunderstorm.

5. If a person counts the number of seconds that pass from the time he sees the lightning and hears the thunder, and divides this number of seconds by 5, the answer will be the number of miles the person is away from the lightning.

G. **Heat lightning** is the flash of lightning from a thunderstorm too far away to be heard.

H. **Sheet lightning** is lightning that takes place within the same cloud.
   1. The flash of lightning cannot be seen, but parts or all of the cloud light up instead.
   2. Sheet lightning is often called heat lightning as well.

PREDICTING THE WEATHER

I. Meteorology

A. **Meteorology** is the science that deals with the study of the weather, which is the condition of the atmosphere at a particular time and place.

B. A **meteorologist** is a person who studies and forecasts the weather.

C. Meteorologists can make fairly accurate weather forecasts by collecting the following information.
   1. The temperature.
   2. The air pressure.
   3. The direction and speed of the wind.
   4. The humidity.
   5. The kind and amount of precipitation.
   6. The condition of the sky.

D. To collect this information, the meteorologist uses a wide variety of weather instruments.

II. Measuring the Temperature of the Air

A. A **thermometer** is used to measure the temperature of the air.

B. One kind of thermometer that meteorologists use is the **liquid thermometer.**
   1. This thermometer is very much like the household thermometer.
   2. It has a hollow, glass tube with a liquid, usually mercury, in it.
   3. The mercury expands and rises when heated, and it contracts and falls when cooled.
   4. The temperature scale on the weather thermometer is either the Fahrenheit (F) scale, or the Centigrade (C) scale, which is now officially called the Celsius scale.
   5. The United States uses the Fahrenheit scale, but the rest of the world uses the Centigrade scale.

C. Meteorologists also use a **metal thermometer.**
   1. This thermometer does not have a liquid in it, but it uses a strip of metal made up of two different heat-sensitive metals that have been welded together.
   2. The metals expand and contract differently when heated and cooled, and this unequal expansion and contraction make the metal strip bend or twist.
   3. The metal strip is wound into a coil, and a pointer is attached to the outside free end of the coil.
   4. When the metal strip bends or twists, the pointer moves across a temperature scale and shows the temperature.

D. A **thermograph** is a metal thermometer that records the temperature continuously all day.
   1. In the thermograph there is a sheet of paper marked with the temperature scale, and this paper turns on a cylinder.

2. A little pen at the end of the pointer makes it possible for the pointer to draw a line on the paper and produce a permanent record of the temperature all day.
3. This permanent record will also show the maximum, or highest, temperature and minimum, or lowest, temperature for that day.

E. Because metal thermometers are not as accurate as liquid thermometers, a special liquid **maximum and minimum thermometer** is used to record the highest and lowest temperatures during a day.

1. Like a regular liquid thermometer, this special thermometer shows the temperature of the air at any particular time.
2. However, it also has special indicators in it, which stay at the highest and lowest temperatures for that day.

III. Measuring Air Pressure

A. The **barometer** is used to measure air pressure.

B. Two kinds of barometers are commonly used: the **mercury barometer** and the **aneroid barometer.**

C. The mercury barometer is a narrow, glass tube about 36 inches long, sealed at one end, that has been filled with mercury and then turned upside down into a dish of mercury.

1. Some of the mercury runs out of the tube until the pressure of the air on the mercury in the dish just supports a column of about 30 inches of mercury that remains in the tube.
2. When the air pressure becomes greater, or increases, the air now pushes harder on the mercury in the dish, making the mercury in the tube rise.
3. The mercury moves easily up the tube because there is no air in the space above the level of the mercury, so there is nothing to slow down or stop the upward movement of the mercury.
4. When the air pressure becomes smaller, or decreases, the mercury moves down the tube.
5. The height of the mercury in the tube is a measure of the pressure of the air at that time.

D. The aneroid (meaning "without liquid") barometer does not use mercury at all.

1. It has an airtight metal can from which some of the air has been removed.
2. This removal of air makes the can very sensitive to changes in air pressure.
3. When the air pressure increases, the springy top of the can is pushed down.
4. When the air pressure decreases, the springy top of the can moves up.
5. This up-and-down movement is passed onto a pointer that moves across an air-pressure scale.
6. The aneroid barometer is sturdier and less awkward to use than the mercury barometer.

E. A **barograph** is an aneroid barometer that has a pen at the end of the pointer and uses a revolving sheet of paper with an air-pressure scale on it so that there is a continuous record of the changes in air pressure during the day.

F. Air pressure can be expressed in two ways.

1. It can be expressed in **inches** or **millimeters of mercury,** showing the height of a column of mercury that could be supported by a particular air pressure.
2. It can be expressed in **millibars,** which are international air pressure units used by physicists.

G. On the weather map, air pressure is shown by **isobars,** which are solid lines that join points throughout the United States where the air pressure is the same.

H. Falling air pressure means a low is coming, bringing bad weather with it.

I. Rising air pressure means a high is coming, bringing good weather with it.

IV. Measuring Wind Direction and Speed

A. A **wind vane** is used to measure the wind direction.

1. The wind vane that is commonly used looks like an arrow.
2. This arrow is mounted on a pole in such a way that it can swing freely when the wind blows on it.
3. The arrow has a broad tail, and the wind strikes this tail, making the arrow swing so that the head points to the direction from which the wind comes.
4. Winds are always named according to the direction from which they come so that a south wind is one that comes from the south.
5. The south wind strikes the tail of the wind vane and makes the head point toward the south.
6. At airports, wind socks are used instead of weather vanes to show wind direction.

B. An **anemometer** is used to measure wind speed, or velocity.

1. The most common type of anemometer has three hollow cups, all facing the same way.
2. The hollow parts of the cup catch the wind and begin to move.
3. The stronger the wind, the faster the cups move.
4. The anemometer expresses wind speed in miles per hour.

C. Sometimes the weather vane and anemometer are combined into one small instrument.

V. Measuring the Relative Humidity

A. The relative humidity can be found by dividing the actual amount of water vapor in the air (absolute humidity) by the maximum amount of water vapor the air can hold at that temperature, and multiplying the result by 100 to express the relative humidity in percentages.

B. A **hygrometer** is used to measure relative humidity.

C. One common form of hygrometer is the **psychrometer,** or **wet-and-dry-bulb thermometer.**

1. The psychrometer has two thermometers that are exactly the same, except that one of the thermometers has a water-soaked cotton cloth or wick wrapped around its bulb.
2. Air is made to pass across both thermometer bulbs, either by whirling the thermometers around or by fanning them with an electric fan.
3. The moving air does not affect the dry thermometer bulb, and the thermometer shows the temperature of the air around it.
4. However, the water in the wet cloth evaporates, taking from the thermometer bulb inside the cloth the heat it needs to evaporate.
5. This evaporation cools the thermometer bulb and makes the temperature fall.
6. The drier the air, the faster the water in the cloth evaporates, the cooler the bulb becomes, and the lower the reading of the "wet" thermometer.
7. When the temperature of the "wet" thermometer has reached its lowest point, the meteorologist finds the difference in temperature between the "wet" thermometer and "dry" thermometer.
8. The meteorologist then uses this difference in temperature to find the relative humidity by consulting a carefully worked out relative humidity table.

D. The **hair hygrometer** uses a bundle of human hairs to find the relative humidity.

1. Human hair is very sensitive to moisture, becoming longer when the air is humid and shorter when the air is dry.
2. This change in the length of the bundle of human hairs makes a pointer move across a scale, from which the relative humidity can be read directly in percentages.

E. The **hygrograph** is a hair hygrometer that uses a pen instead of a pointer and a revolving sheet of paper with the relative humidity scale on it to give a continuous record of the relative humidity.

VI. Measuring Rainfall and Snowfall

A. The rain gauge measures the amount of rainfall.

B. The most common form of rain gauge is a narrow cylinder with a funnel on top.
  1. The area of the mouth of the funnel is exactly ten times larger than the area of the mouth of the cylinder.
  2. Therefore, the cylinder receives ten times as much water when the funnel is in it than it would receive alone.
  3. This larger amount of water is easier to measure, but the amount must be divided by 10 to find the correct amount of rainfall.
  4. To measure the amount of rain collected in the cylinder, a marked stick is dipped into the cylinder.
  5. Rainfall is measured in inches, and in tenths or hundredths of an inch.

C. Snowfall can be measured with a rain gauge, or by measuring an open location.
  1. A measuring stick is used to find the height of the snow.
  2. Snowfall is usually measured in inches or tenths of an inch.

D. Meteorologists also find out how much rain the snowfall might have produced.
  1. To determine this amount they melt and weigh a certain number of inches of snow.
  2. Because snow can be light and fluffy, or heavy and wet, the amount of rainfall that snow might have produced varies.
  3. A light, fluffy snow may produce 1 inch of rain for every 20 inches of snow, but a heavy, wet snow may produce 1 inch of rain for every 5 inches of snow.
  4. As an average, 10 inches of snow make 1 inch of rain.

VII. Measuring Weather Conditions at High Altitudes

A. The radiosonde is an instrument used to measure weather conditions at upper levels of the air.
  1. It contains a small thermometer, barometer, and hygrometer.
  2. It also has a small radio transmitter that automatically sends out signals showing the temperature, pressure, and relative humidity of the air through which the radiosonde is passing.
  3. The 2-pound radiosonde is attached to a 6-foot balloon filled with helium.
  4. This balloon can travel 10 to 15 miles into the stratosphere before the balloon bursts.
  5. A parachute opens when the balloon bursts, and it allows the radiosonde to return undamaged to earth.

B. Radar is also used to measure and predict the weather.
  1. Cloud droplets and raindrops reflect the radar waves and show up on the radar screen.
  2. Radar can also locate storms and tell how much area they are covering.
  3. It can watch how a storm forms and moves across the earth.
  4. It can measure the speed of high-altitude winds by tracking a balloon as it moves through the air at high levels.
  5. It can track hurricanes, locate the "eye" of the hurricane, follow the movement of the hurricane, and predict its path.

VIII. The United States Weather Bureau

A. The United States Weather Bureau in Washington, D.C., provides weather information and services for the entire United States.

B. To get this information, observations are made at about 600 official Weather Bureau stations throughout the United States.
  1. Information is also sent from stations in Canada, Mexico, Cuba, northern South America, Europe, northern Africa, and Asia.
  2. Observers on ships also send information daily.
  3. Observations are made four times a day, every 6 hours, and all the information is

sent to the central office in Washington, D.C.

C. The central office then draws a weather map and sends the information on it by radio, teletype, or wirephoto to all the forecast centers in the country.

D. To draw a weather map, the Weather Bureau needs the following information from its observers.
   1. The temperature of the air.
   2. The air pressure and changes in the air pressure in the past 3 hours.
   3. The relative humidity and dew point.
   4. The wind direction and speed.
   5. The condition of the sky and the present weather.
   6. The kind, height, and amount of clouds.
   7. The visibility.
   8. The weather in the past 6 hours.
   9. The kind and amount of precipitation in the past 6 hours.
   10. The time the precipitation began and the time it ended.

E. The Weather Bureau puts this information in the map, using symbols to fit all of it on the map.

F. The Weather Bureau also provides other services.
   1. It makes detailed 24-hour weather forecasts, changing them twice a day if necessary.
   2. It makes general 5-day forecasts, which are published in newspapers or announced over radio and television stations.
   3. It provides weather and crop bulletins for farmers.
   4. It gives hurricane, tornado, and severe storm warnings.
   5. It gives frost warnings for fruit and crop farmers.
   6. It forecasts floods.
   7. It offers special information and forecasts for planes, sending this information to 17 aviation centers every 6 hours by teletype.
   8. It has special forecasts for ships.

G. Almost every person in the United States is helped by the work of the Weather Bureau.
   1. The daily forecast helps us decide what to wear.
   2. It helps railroads, trucks, and ships protect shipments of perishable foods.
   3. It gives gas, light, and power companies the chance to be ready for extra service when a cold spell or storm is coming.
   4. It gives cities a chance to prepare their snow removal equipment for a coming snow storm.
   5. It gives farmers a chance to save their crops from being killed by frost.
   6. It helps save lives by warning persons of hurricanes, tornadoes, and floods.

IX. Man-Made Weather

A. Man is constantly trying to control the weather.

B. In some cases man has been able to get supercooled clouds high in the sky to give up their moisture.
   1. By dropping small particles of dry ice, silver iodide, or other crystals into these clouds, man has caused some of the cloud droplets to become ice crystals.
   2. These ice crystals grow larger as the water vapor in the cloud condenses on them.
   3. When the ice crystals are large enough, they fall as snow.
   4. This snow turns to rain when it falls into lower, warmer air.

C. Man has also invented devices that are able to reduce or eliminate fog on airport landing fields.

CLIMATE

I. Weather and Climate

A. **Weather** is the condition of the atmosphere at a particular time and place.

B. **Climate** is the average weather of a place over a period of years.

C. A scientist who studies the climate is called a **climatologist**.

D. Climatologists have discovered many factors that affect the kind of climate found in different parts of the earth.

E. These factors of climate can be divided into two classes.

1. The first class consists of those factors that control the yearly temperature of a particular place.
2. The second class consists of those factors that control the yearly rainfall of that place.

II. Factors That Control the Yearly Temperature

A. **Latitude** influences temperature more than any other factor.

1. The latitude of a region or place is its distance from the equator.
2. A region near the equator is said to have a low latitude, and a region near the poles is said to have a high latitude.
3. The higher the latitude of a place, the colder its climate will be.
4. Near the equator, where the sun's rays are direct almost all year and the days and nights are equally long, there is the same hot climate throughout the year.
5. Halfway between the equator and the north pole, the sun's rays are direct during the summer and the days are much longer than the nights so that the summers are hot.
6. However, during the winter the sun's rays are slanted and the nights are longer than the days so that the winters are cold.
7. Near the poles, the sun's rays are always slanted.
8. During the summer near the poles, the sun shines all 24 hours of the day for months, and the weather is still cold, but it is mild in comparison with the winter.
9. During the winter near the poles, the sun does not shine for months, and the weather is bitterly cold.

B. The higher the **altitude** of a place, the colder its climate will be.

1. Altitude is the height above sea level.
2. Even near the equator, if a city is located at a high altitude, its weather and climate will be much cooler than a city located at sea level.

C. Land and water masses affect the climate of a place.

1. Land masses heat up and cool down more quickly than water masses.
2. As a result, land regions are more likely to have hot summers and cold winters, and sea regions in the same latitude are more likely to have cooler summers and milder winters.

D. The direction of the prevailing winds affects the climate of a continent's seacoasts.

1. On the northwest coast of the United States the prevailing westerlies blow in from the warm Pacific Ocean so that the northwest coast has a cool summer and mild winter.
2. On the northeast coast of the United States the prevailing westerlies blow from the land out to the ocean so that the northeast coast has a hot summer and cold winter.

E. Mountain ranges and plains decide how much far-away winds affect a region's climate.

1. The high Rocky Mountains stop the mild west-coast climate from extending any further into the Great Plains.

2. At the same time, the level Great Plains allow very cold winds to speed from the poles all the way to the Gulf of Mexico, and allow hot winds from the south to move north.
3. As a result, the Great Plains have hot summers and cold winters.

F. Ocean currents can make the climate of a region much warmer or colder than normal for the region's latitude.
1. The prevailing westerlies, blowing from the warm Gulf Stream, give the British Isles and northwestern Europe climates just as warm as those of regions hundreds of miles nearer the equator.
2. At the same time, winds from the cold Labrador Current give northern Labrador a climate much colder than that of a region, such as southern Sweden, which has the same latitude.

III. Factors That Control the Yearly Rainfall

A. Latitude also affects the amount of rainfall a region receives.
1. The latitude decides in which wind belt a region will be located during the year.
2. Places where warm, moist wind is rising will have rainy weather, and places where cool, dry air is falling will have dry weather.
3. Places in the doldrums will have heavy rains all through the year.
4. Places in the trade winds and horse latitudes will be mostly dry during the year.
5. Places in the prevailing westerlies will have moderate rainfall all year.
6. Places in the polar easterlies will have light snow all year.

B. Because wind belts shift during the year, as the earth revolves around the sun, some places may be in a rainy belt for part of the year and in a dry belt for the other part of the year.

C. Sometimes seasonal wind changes give a region a dry season and a wet season.
1. The seasonal winds, or monsoons, of India produce wet and dry seasons.
2. In the summer the Indian Ocean is cooler than the hot land so that a warm, moist monsoon blows from the ocean over the land, bringing rainy weather from May through October.
3. In the winter the land is cooler than the Indian Ocean so that a cold, dry monsoon blows across the land out to the sea, bringing dry weather from November through April.

D. Mountains affect the amount of rainfall a region will receive.
1. When warm, moist wind strikes the windward side of the mountain and rises, there is much rainfall on this side.
2. However, the leeward or protected side will now have very little rain because most of the water vapor will have already condensed from the air before the air passed over the mountain to the leeward side.

E. When winds blow in from the ocean, the regions nearest the ocean get the most rainfall.
1. This distribution occurs because the moisture condenses out of the ocean air as it blows across the land.
2. The warmer the ocean, the heavier the rainfall will be.

F. When ocean currents are much warmer or colder than the land or water around them, much fog is formed.
1. The warm Gulf Stream air striking the cold British Isles causes a lot of fog.
2. In the summer New England has a lot of fog when the warm winds coming up from the south are cooled by the cold waters of the New England coast.
3. When the warm Gulf Stream air blows over the cold Labrador Current in the Grand Banks, thick fogs are formed.

IV. Classification of Climates

A. Climatologists no longer classify climates according to torrid, temperate, and frigid zones.

B. Today they divide the earth into **tropical, middle latitude,** and **polar** climates.

C. Each of these climates is subdivided into different types of climates, depending upon the temperature and rainfall they have.

V. The Tropical Climates

A. Three different types of climates are included under the classification of tropical climates: the **tropical rain forest,** the **savanna,** and the **desert** climates.
   1. These climates are all located within 30 degrees latitude above and below the equator.
   2. They all have an average yearly temperature of at least 68 degrees Fahrenheit, but they differ in the amount of rainfall they get.

B. The tropical rain forest climate is found in regions at or close to the equator.
   1. The regions in this climate have heavy rainfall all year, and the temperature is always high.
   2. Because of these two conditions, there is a heavy growth of plants, forming a jungle.
   3. The relative humidity is always high, and there is usually a thundershower every afternoon.
   4. The African Congo, Amazon Valley, east coast of Central America, Madagascar, and Indonesia have this climate.

C. The savanna climate is found farther away from the equator.
   1. The regions in this climate have wet and dry seasons as the wind belts shift during the year.
   2. When these regions are in the doldrums, there is heavy rainfall.
   3. When the wind belts shift, the regions now lie in the trade winds and have little or no rain.
   4. Mostly coarse grasses and a few trees grow in these regions, which are called savannas.
   5. The Sudan of north Africa, the veldt of south Africa, campos of Brazil, llanos of Venezuela, downes of Australia, and parts of India and Burma all have this climate.

D. The desert climate is even farther away from the equator.
   1. The regions in this climate are always in the wind belt of the trade winds so that they get practically no rainfall at all.
   2. As a result, few plants grow in these regions.
   3. When the rain does come, it falls as a thundershower or cloudburst.
   4. Sand deserts are found in this climate.
   5. Because there is very little moisture in the air, the days are very warm and the nights are quite cool.
   6. The Sahara, Arabian, American, Kalahari (south Africa), Australian, and Peruvian Deserts are found in this climate.

VI. The Middle Latitude Climates

A. Six different types of climate are included under this classification of middle latitude climates: the **Mediterranean, humid subtropical, marine west coast, humid continental, dry continental,** and **subarctic** climates.
   1. These climates are all located between 30 degrees and 65 degrees latitude.
   2. Although there is a wide range of temperature in these climates, they all have at least 1 month where the average temperature is 50 degrees Fahrenheit or higher.
   3. The regions in these climates lie mostly in the wind belt of the prevailing westerlies, which produces all kinds of weather.

B. The regions in the Mediterranean climate lie between 30 degrees and 40 degrees latitude in both the northern and southern hemispheres.
   1. These regions are all found on the western side of the continents.
   2. They lie in the trade winds or horse latitudes in the summer, and in the prevailing westerlies in the winter.

3. Their summers are warm or hot and almost completely dry, and their winters are mild and have some rainy months.
4. Fruits, olives, grapes, and nuts grow well in this climate.
5. Because the rainfall is only about 15 to 25 inches a year, this climate is also called the **dry subtropical climate.**
6. Southern California, southern Australia, central Chile, and the lands around the Mediterranean Sea have this climate.

C. The regions in the humid subtropical climate also lie between 30 degrees and 40 degrees latitude, but on the eastern side of the continents.
   1. They do not have a dry season, and the rainfall is much greater, that is, about 35 to 60 inches annually.
   2. The summers are warm and the winters are mild, but there are often cold waves and frosts during the winter.
   3. The humidity is very high in the summer and can become uncomfortable.
   4. Tall grasses and pine forests grow in this climate.
   5. Southeastern United States, eastern and southern Asia and Japan, northern Argentina, and southern Brazil have this climate.

D. The regions in the marine west coast climate lie between 40 degrees latitude and the edges of the polar regions.
   1. These regions are all on the western side of the continents.
   2. They lie mostly in the prevailing westerlies all year so that they get a good supply of rain all year.
   3. Where mountains block the movement of the winds, the rainfall is heavy on the windward side of the mountains.
   4. Because the westerlies blow in from the ocean, the summers are cool and the winters are mild in these regions.
   5. They get more rain and fog in the winter than in the summer.
   6. Hardwood and evergreen trees grow in these regions.
   7. The northwest coast of the United States, the British Isles, Norway, western Australia, New Zealand, and southern Chile have this climate.

E. The regions in the humid continental climate are in the same latitude as those of the marine west coast climate, but they are all on the east side of the continents.
   1. These regions have hot summers and cold winters.
   2. The weather changes are sharp so that the regions get blizzards, very cold spells, heat waves, high humidity, thunderstorms, and tornadoes.
   3. More rain falls in the summer than in the winter, and the rainfall is heavier at the coast.
   4. Where the rainfall is more than 30 inches a year, leafy and evergreen trees grow.
   5. Where the rainfall is less than 30 inches a year, tall grasses grow, forming prairies.
   6. Eastern United States, ranging from much of the Great Plains to the coast, eastern Europe, and eastern Asia have this climate.

F. The regions in the dry continental climate are also in the same latitude as the humid continental and marine west coast climates, but they are located in the interior of the continents.
   1. These regions have hot summers and very cold winters.
   2. Rainfall is light, and more rain usually falls in the summer than in the winter.
   3. Those regions where the rainfall is between 10 and 20 inches a year are called **steppes.**
   4. Those regions where the rainfall is under 10 inches a year are called **middle latitude deserts.**
   5. Low grasses and sagebrush grow in the steppes, and only sagebrush and cactus grow in the middle latitude deserts.
   6. Steppes are found in the midwestern states of the United States, in Argentina, and in Russia.
   7. Middle latitude deserts are found in the western United States, western

Argentina, and the interior of Asia.

G. Most of the regions in the subarctic climate lie between 50 degrees and 65 degrees latitude.

1. These regions have very long, cold winters and short, mildly warm summers.
2. They have less than 15 inches of precipitation a year, and most of this precipitation falls in the summer.
3. In the summer the days are very long, and in the winter the nights are very long.
4. Mostly small evergreen trees grow in this climate.
5. Most of northern Canada, most of Europe north of 60 degrees latitude, and almost all of Siberia have this climate.

VII. Polar Climates

A. Two different types are included under this classification of polar climates: the **tundra** and the **icecap** climates.

1. These climates start where the middle latitude climates end and extend to the poles.
2. These climates have no summer at all because the sun's rays are so slanted that they give very little heat.
3. There is very little precipitation because the air is too cold to hold much water vapor.

B. The tundra climate is a cold climate, beginning where the subarctic climate ends.

1. The average temperature of the warmest month is between 32 degrees and 50 degrees Fahrenheit, and the average temperature of the coldest month is −40 degrees Fahrenheit.
2. The light summer rains permit mosses and lichens to grow.
3. The tundra climate exists only in the northern hemisphere because there are no land areas in this latitude at the Antarctic.

C. The icecap climate is found near the poles, and the temperature never rises above 32 degrees Fahrenheit.

1. The average yearly temperature is between −10 degrees and −30 degrees Fahrenheit, and the lowest temperature ever recorded in this climate was −125 degrees Fahrenheit on the Antarctic icecap.
2. There are always either icecaps or glaciers in this climate.
3. Precipitation falls only as light snow, and there is very little precipitation.

LEARNING ACTIVITIES FOR "WATER, WEATHER, AND CLIMATE"

WATER

1. *The water table* · Fill a large, wide-mouthed glass jar about three-quarters full of a mixture of sand and gravel. Pour water down the side of the glass jar until the water level rises to about half the level of the mixture of sand and gravel (Figure 11–1). This water level will represent the level of the water table. Mark this level on the glass jar, using a wax crayon or marking pencil. Add more water, and the water table will rise.

2. *Permeable and impermeable rock* · Weigh a piece of granite and a piece of sandstone or limestone separately. Soak both stones in a jar of water overnight. The next day remove the stones, wipe their surfaces with a dry cloth, and weigh the stones separately again. The permeable sandstone or limestone will have

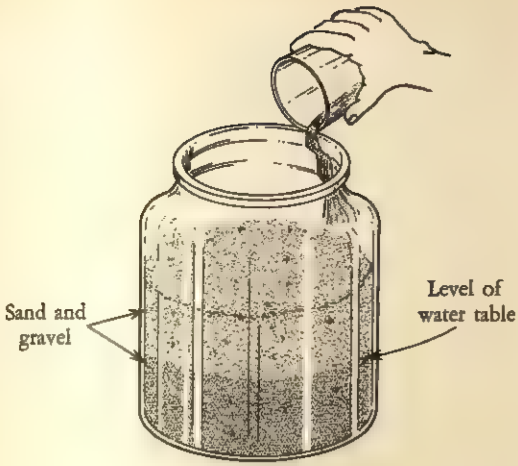


FIGURE 11–1.
HOW THE WATER TABLE IS FORMED.

absorbed water and gained weight. The impermeable granite will not have absorbed any water, and its weight will not have changed.

3. *Swamps and springs* · Draw a diagram on the chalkboard showing that, where the land surface dips below the water table, groundwater flows out to the surface, forming springs or contributing to the water in swamps and lakes (Figure 11–2). Point out that during dry periods the level of the water table sinks, and some streams and swamps may dry up.

If possible, visit a swampy area in early spring, when the water table is nearer the land surface than at any other time of the year. Sometimes it is possible to reach the water table just by digging a small hole with a shovel.

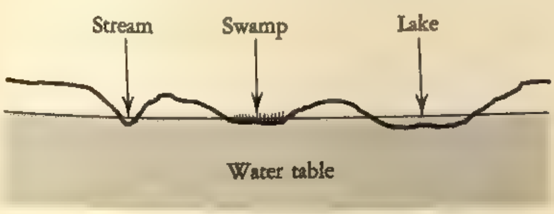


FIGURE 11–2.
SWAMPS, STREAMS, AND LAKES ARE FORMED WHEN THE LAND SURFACE DIPS BELOW THE WATER TABLE.

4. *Lakes* · Find out all you can about the lake or lakes located in or near the area where you live. Learn how the basin was formed, and contrast this method of formation with the other ways that lake basins can be formed. Find out how your lakes get their water. Discuss the different ways that lakes can be destroyed, and suggest some measures that could be taken to prevent this from happening.

5. *Purify water by distillation* · Fill a glass jar one-half full with water. To the water add some food coloring, a tablespoon of salt, and some soil. Shake the mixture well, and then pour it into a tea kettle. Obtain a long piece of rubber tubing. Place one end of the rubber tubing inside the spout of the tea kettle and use modeling clay in and around the spout to hold the rubber tubing in place and to make sure that the steam will pass out only through the tubing (Figure 11–3). Place the other end of the rubber tubing into a glass tumbler that has been placed in a pan filled with ice cubes. Now place the tea kettle on a hot plate. When the water boils, drops of water will condense in the tumbler or drip from the hose into the tumbler. This water will be clear and pure, and it will not taste salty. When the water in the tea kettle boiled and changed into water vapor or steam, the impurities were left in the tea kettle. Only pure, clean water condensed

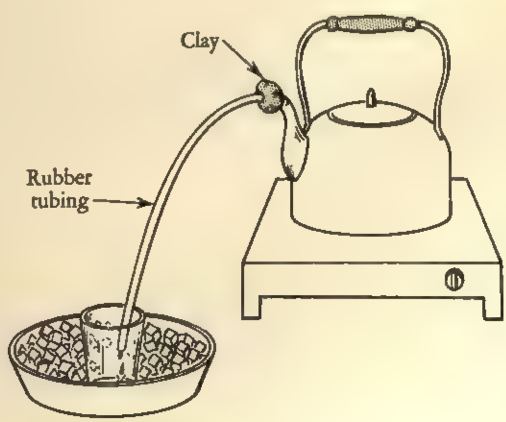


FIGURE 11–3.
DISTILLATION PURIFIES WATER.

as the steam was cooled in the tumbler.

6. *Purify water by settling* · Fill a glass jar about three-quarters full of water. Add a mixture of coarse and fine soil to the jar, shake the contents thoroughly, and then set the jar down and allow the soil to settle. The coarse soil will quickly settle to the bottom, but it may take many days for the fine soil to settle completely.

7. *Chemicals help settle muddy water* · Get two glass jars that are the same size, and fill each jar about three-quarters full of water. To each jar add a small amount of fine soil, shake the jars thoroughly, and then set the jars down. The finely divided bits of soil will be suspended in the water. Now add a teaspoon of alum crystals and a teaspoon of ammonia to a glass tumbler that is about one-quarter full of clear water. Stir the water well in the glass tumbler, and then pour the contents into one of the glass jars. The particles of fine soil will stick to the jellylike material that is formed, and will be carried to the bottom as the material settles. Compare the appearance of the chemically treated water with that of the untreated water in the jar that serves as a control.

8. *Purify water by filtering* · To a large plastic or glass funnel add a layer of small pebbles, then a layer of gravel or coarse sand, and finally a layer of fine sand (Figure 11–4). First pour some clean water through the funnel to allow the layers to settle and pack together. Then place the funnel in a narrow-mouth glass jar and pour some muddy water into the funnel. The layers will filter the mud, and clear water will pass into the jar.

9. *Destroy bacteria in water* · If your local water supply is chlorinated, fill a pan with cold water and heat the pan on a hot plate. You will be able to smell the chlorine by sniffing close to the top of the pan. If your local water supply is very lightly or not at all chlorinated, add a few drops of a chlorine bleach to a tumbler of water, and have the children smell the chlorine, which acts as a germicide.

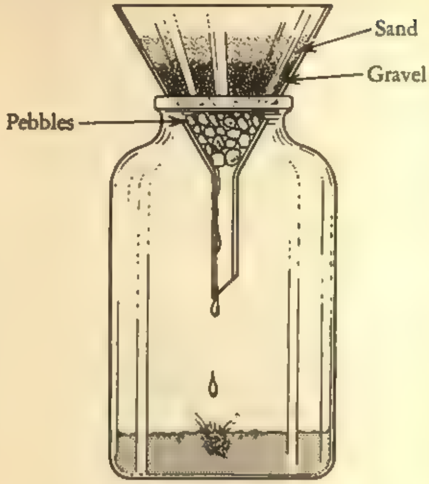


FIGURE 11–4.
FILTERING HELPS PURIFY WATER.

10. *Fluorides in water* · If your local water supply has fluorides added, find out the amount used. Discuss the value of adding fluorides to water, and collect information about the results of using fluorides in water for a period of years to prevent tooth decay.

11. *Make and soften temporary hard water* · Obtain some limewater from the drugstore. Pour limewater into a test tube until it is half full and, using a soda straw, bubble carbon dioxide from your breath through the limewater. At first the limewater will become milky, but continue the bubbling until the milkiness disappears. Pour an equal amount of distilled water or rainwater into a second test tube. Make a soap solution by dissolving soap shavings in warm water. Now add an equal number of drops of soap solution to each of the test tubes and, while holding a thumb over the mouth of each test tube, shake the test tubes vigorously. The soft water will make lots of suds, but the temporary hard water will make very few suds and form curds instead.

Make some more temporary hard water and boil it for a few minutes to remove the hardness. Add the same amount of soap solution as you did to the other two test tubes, and note how the boiled water now makes lots of suds.

12. *Make and soften permanent hard water* • To a test tube half full of water add a small amount of Epsom salts (magnesium sulfate), shaking the test tube until the salt dissolves. Pour the same number of drops of soap solution (as prepared in Learning Activity 11 above) into the test tube containing the freshly prepared permanent hard water and into a test tube containing an equal amount of distilled water or rainwater. Shake both test tubes vigorously and note the difference in amount of suds produced.

Soften the permanent hard water by adding some washing soda, borax, or ammonia. Now add the same number of drops of soap solution as you did to the other two test tubes, and note the increased amount of suds formed.

13. *The action of detergents* • Obtain some high-sudsing detergent. Prepare samples of temporary and permanent hard water (as described in Learning Activities 11 and 12 above). Obtain three test tubes. Pour some temporary hard water into one test tube, an equal amount of permanent hard water into the second test tube, and an equal amount of distilled water or rainwater into the third test tube. Now add the same amount of detergent to each test tube and shake the test tubes vigorously. Note that all three test tubes have lots of suds, showing that the sudsing (and cleaning) action of detergents is not affected by water hardness.

14. *Commercial water softeners* • Have the children report on the use and treatment of such chemicals as zeolite and resins for softening water in homes and factories.

15. *Water exerts pressure* • Obtain a tall tin can. Place a piece of two-by-four wood, or any other piece of wood of suitable thickness, in the can. Use a hammer and large nail to punch a hole in one side of the can near the bottom (Figure 11–5). Now bring the can to the sink and, while keeping one finger over the hole, fill the can with water. Release your finger and a stream of water will shoot out some distance

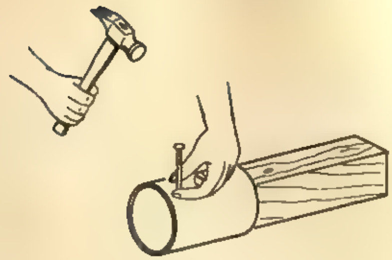


FIGURE 11–5.
USING A PIECE OF WOOD TO PUNCH A HOLE IN ONE SIDE OF A CAN.

from the hole, showing that water exerts pressure.

16. *Water pressure is the same in all directions* • Use a hammer and large nail to punch holes all around the sides of a tall tin can near the bottom (Figure 11–6). It may be helpful to use a block of wood (as described in Learning Activity 15) when making the holes. Bring the can to the sink and run water into the can rapidly so that it stays full while the water is

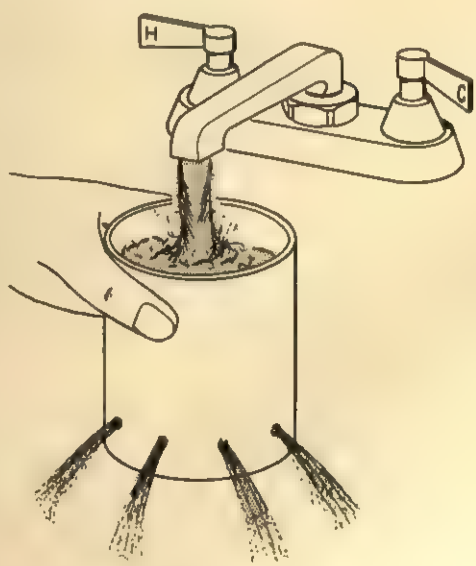


FIGURE 11–6.
WATER EXERTS THE SAME PRESSURE IN ALL DIRECTIONS.

escaping through the holes. Note how the water shoots out exactly the same distance from all the holes.

17. *Depth affects water pressure* · Use a hammer and large nail to punch three holes along one side of a tall tin can, using a block of wood (as described in Learning Activity 15) if necessary. One hole should be near the top of the can, another hole in the middle, and the third hole near the bottom (Figure 11–7). Bring the can to the sink and run water into the can rapidly so that it stays full while the water is escaping through the holes. Point out that the greater the depth of the water, the farther it will shoot out of the hole.

18. *Hydraulic lift* · Have the children visit a local gas station, where the attendant can demonstrate the hydraulic lift and explain how it is used to raise a car. Have the children find examples of other hydraulic machines and their uses.

19. *Moving water does work* · Make a water turbine from the round top of a large tin can. Use a hammer and nail to punch a hole in the center of the tin. With a pencil or crayon divide the tin into eight equal sections extending from the center. Use a tin snips to cut along the pencil lines of each section to about ½ inch from the hole in the center. Then twist each segment with pliers to form blades that are almost at right angles to the flat part of the tin (Figure 11–8). Obtain a knitting needle

FIGURE 11–7.
THE DEEPER THE WATER, THE GREATER THE WATER PRESSURE WILL BE.

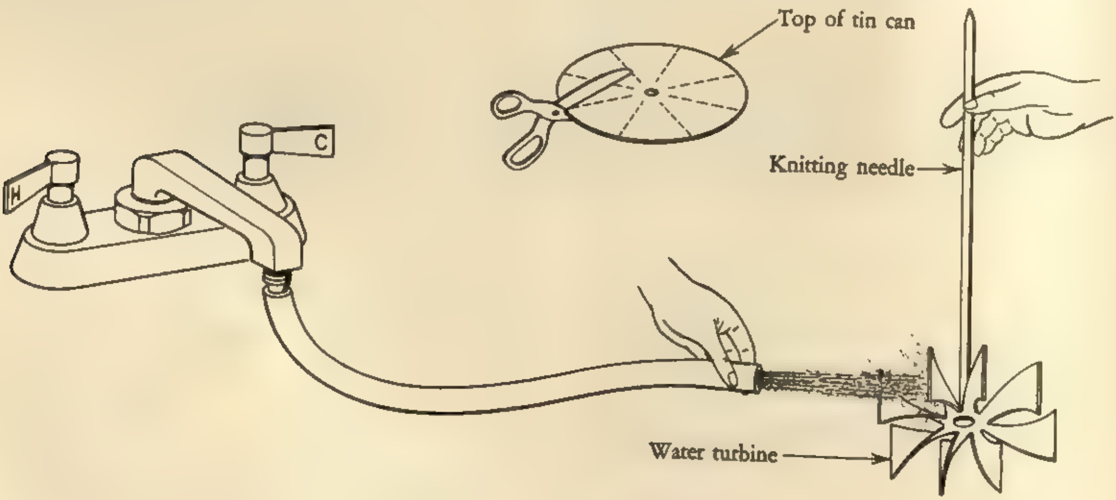


FIGURE 11–8. A WATER TURBINE.

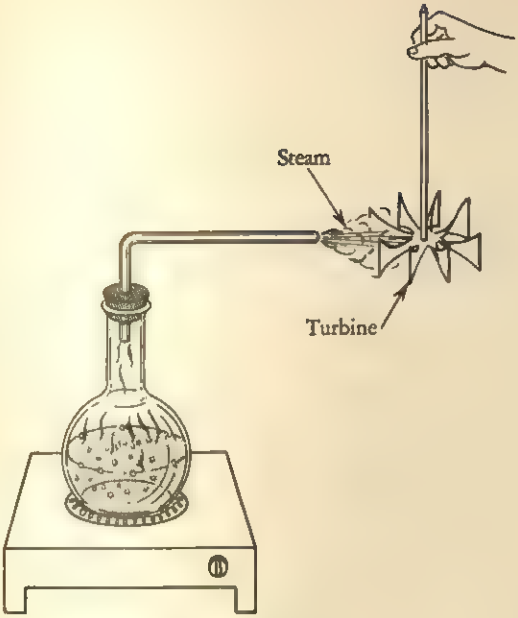


FIGURE 11–9.
A STEAM TURBINE.

that has a head at one end, and pass the pointed end of the needle through the hole in the tin. The smooth part of the tin should be next to the head of the knitting needle. Attach the rubber tubing from a portable bath spray to a faucet. Turn on the faucet and pinch the end of the rubber tubing so that a narrow but fast stream of water comes out of the tubing. Direct this stream against the blades of the water turbine, making it spin very rapidly.

20. *Steam does work* · Make a steam generator (Figure 11–9), using a large Pyrex flask, a one-hole rubber stopper, and a piece of glass or plastic tubing bent at right angles. The rubber stopper should not be pressed too tightly into the neck of the flask so that, if steam should form too quickly and build up pressure, the steam would be able to blow the stopper quite easily from the flask. Add water to the flask and heat the flask on a hot plate. Heat the water until it boils and steam is escaping freely from the glass tubing. Make a turbine as described in Learning Activity 19 above. Hold the turbine in the path of the steam so that the steam strikes the blades directly, making the turbine spin rapidly.

21. *The downward pull of gravity* · Repeat Learning Activity 5 of "The Solar System," (p. 276). This time put objects of different sizes and weights on the child's outstretched palm. The downward pull of gravity of small, heavy objects (like stones) will be greater than that of large, light objects (like balsa wood). Point out that the heavier the object, the greater the downward pull of gravity will be.

22. *Water exerts an upward buoyant force* · Have the children try pushing a beach ball or volleyball into a tub of water. The upward buoyant force exerted by the water will be felt quite noticeably.

23. *A body seems to lose weight in water* · Tie a string around a stone, connect it to a spring balance, and note the weight of the stone in air (Figure 11–10). Now lower the stone in a large, wide-mouthed jar half filled with water. Read the weight of the stone again, and note the loss in weight caused by the upward buoyant force of the displaced water.

24. *A floating body displaces its own weight of water* · Make an overflow can. Obtain a

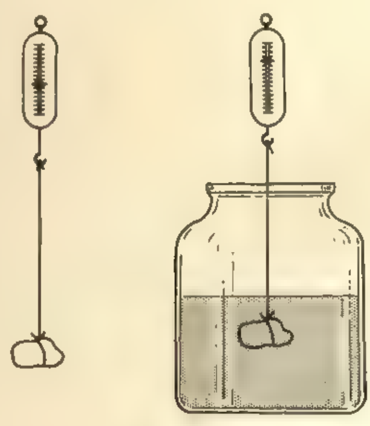


FIGURE 11–10.
WHEN LOWERED INTO WATER, THE ROCK SEEMS TO LOSE WEIGHT.

large tin can. By using tin snips, make two cuts down one side of the can. Make the cuts 2 inches apart and 3 inches long. Now bend this loose strip of metal outward and slightly downward, and shape it so that it makes a V-shaped trough (Figure 11–11). Coat the underside of

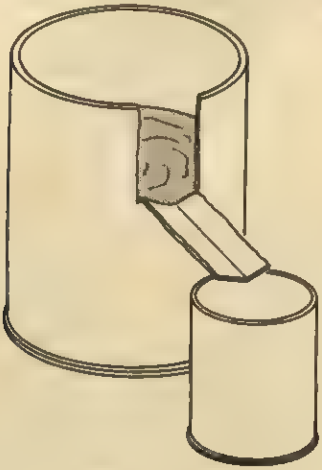


FIGURE 11–11.
AN OVERFLOW CAN.

the lip of this trough lightly with Vaseline. Pour water into the tin can until the water inside the can is just level with the trough. Obtain a block of wood that will fit inside the can and weigh the wood. Obtain a smaller tin can and also weigh the tin can. Now position the smaller tin can so that its center is directly underneath the lip of the trough. Lower the block of wood gently into the large tin can containing the water. The displaced water will overflow into the smaller empty can. When the water stops overflowing, weigh the smaller tin can again. Subtract the weight of the smaller tin can from the combined weight of the overflow water and tin can. The difference will be the weight of the overflow water. Compare the weight of the overflow water with the weight of the block of wood. The weights should be just about the same.

25. *Why a steel ship floats* • Cut out two pieces of aluminum foil 6 inches long and 4 inches wide. Fold one piece in half again and again, flattening the foil each time with your fingers to remove any trapped air, until you have a small, flat wad of aluminum. Drop this wad of aluminum in a pie tin full of water, and the aluminum will sink to the bottom because it displaces very little water to produce a small upward force. Shape the second piece of aluminum foil with your fingers until you have a figure similar to a rectangular boat. Place this boat in the water; it will float because it displaces a large amount of water to produce a large upward force.

26. *The effect of more cargo on a ship* • Place a small rectangular cake tin in a rectangular glass aquarium almost full of water. Note how much the bottom and sides of the empty cake tin sink below the level of the water. Now spread a few stones evenly along the bottom of the cake tin. The tin sinks more deeply in the water, displacing enough water to support the added weight of the stones.

27. *Salt water is more buoyant than fresh water* • Obtain two large, wide-mouthed jars and fill them about three-quarters full of water. Add salt to the water in one jar, stirring vigorously, until no more salt will dissolve. Now place an egg, first in the fresh water and then in the salt water (Figure 11–12). The egg will float in the heavier, more buoyant salt water.

28. *Conservation of water* • Adjust a water faucet so that there is a steady drip of water. See how much water will drip into a glass

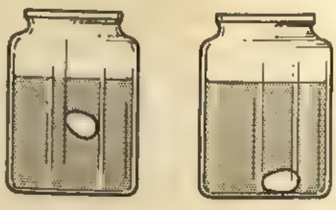


FIGURE 11–12.
AN EGG WILL SINK IN FRESH WATER AND FLOAT IN SALT WATER.

measuring cup in 1 hour. Calculate the amount of water that would be wasted in 1 day. Multiply this by the probable number of water users in your community. List other ways in which water is wasted needlessly.

29. *Water pollution* · Look for signs of water pollution in nearby rivers and streams. Note the effect on plant and animal life. Make a large amount of suds in the sink, using a high-sudsing detergent. Note how difficult it is to wash these suds quickly down the drain. Collect information about the difficulty bacteria have in disposing of detergent suds in rivers, and the effect of these suds on plant and animal life in streams.

THE OCEANS

1. *Exploring the ocean* · Have the children read about the purpose and function of the different kinds of instruments used to study the ocean, and report some of the more pertinent findings made with these instruments. The reports of studies made during the most recent International Geophysical Year will supply interesting information about the topography of the ocean.

2. *Seawater contains salts* · Pour some seawater in a saucer and let the water evaporate completely. Have the children taste the white crystals that were deposited in the bottom of the saucer. If seawater is unavailable, use salt water instead.

3. *Icebergs* · Place a square or rectangular ice cube in a tumbler of water. Note how much (about nine tenths) of the ice cube is below the surface of the water. Collect and display pictures of icebergs. Point out that although the icebergs are huge, only about one tenth of the whole iceberg can be seen above the surface of the water.

4. *The wind causes waves* · Pour some water into a large soup plate. Blow hard at one end of the plate across the water (Figure 11–13). The water will ripple and form waves. The stronger you blow, the larger the waves will be. Discuss the parts of a wave, and show how white caps, breakers, undertows, and tsunamis are formed.

5. *Locate the major ocean currents* · Obtain a map of the world and locate the major ocean currents. Trace their movements for both hemispheres.

6. *The effect of the earth's rotation on ocean currents* · Obtain a globe of the earth that can spin. Spin the globe very slowly in a counterclockwise direction (from west to east). At the same time pour a small amount of fairly thick blue washable paint in a thin stream onto the north pole. As the stream flows down the northern hemisphere, it is deflected to the right (to the west) by the earth's rotation. When the stream crosses the equator and enters the southern hemisphere, it is now deflected to the left (to the east). It can be made equally obvious that ocean currents moving north are deflected to the right (to the east), and currents moving south are deflected to the left (to the west). This demonstration will help to show the children why the ocean currents have a clockwise circulation in the northern hemisphere and a counterclockwise circulation in the southern hemisphere.

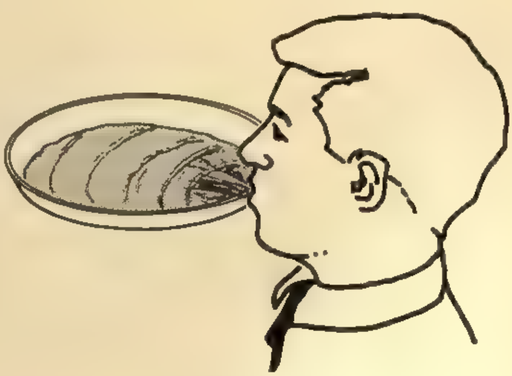


FIGURE 11–13.
MAKING WAVES.

7. *Winds help cause deep sea currents* · Repeat Learning Activity 4 above, blowing across one end of a large soup plate filled with water. Point out that the water moved away on the surface by the wind may be replaced by water from below. This displacement helps create movement of water below the surface, producing a deep sea current.

8. *Economic importance of the oceans* · Let the children learn about the extraction of magnesium, bromine, and other chemicals from the ocean, and the uses of these chemicals in our daily life. Give reports of the commercial fishing industry and locate the important fishing areas of the world.

WINDS

1. *The earth is heated unequally by the sun* · Put the same amount of soil into each of two cardboard or wooden boxes. On a sunny morning or afternoon place both boxes into the sunlight. Let one box lie flat so that it receives slanted rays from the sun, and prop up the other box so that the sun's rays strike it directly (Figure 11–14). Place thermometers that have the same reading into each box, inserting both thermometers into the same depth of soil. Take temperature readings every 10 minutes. The soil that receives the direct rays of the sun will become warmer. Point out that the earth's equator receives direct rays whereas the rays become more and more slanted in the northerly and southerly latitudes. Also point out that the air above the earth will be heated unequally as well.

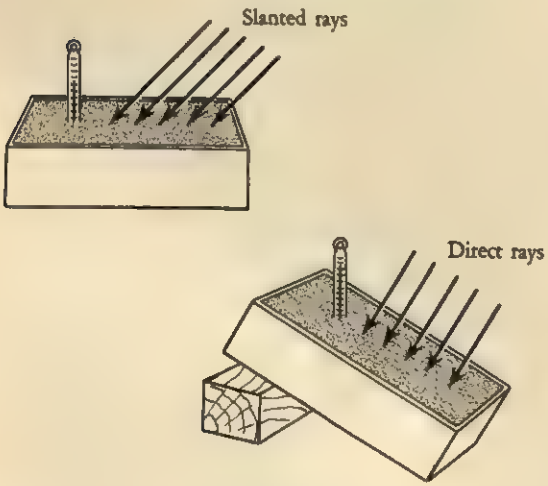


FIGURE 11–14.
DIRECT RAYS HEAT THE EARTH MORE THAN SLANTED RAYS.

2. *Dark surfaces absorb radiant energy more quickly than light surfaces do* · Obtain two tin cans of exactly the same size. Paint the outside of one can with flat, black paint, and paint the outside of the other can with white paint. Now add equal amounts of water into each can so that the cans are about one-half to three-quarters full. Place a thermometer in each can (the thermometers must have the same reading) and place both cans in the sunlight (Figure 11–15). Record the temperature reading every 15 minutes for 1 hour. The water in the black can will become warmer than the water in the white can.

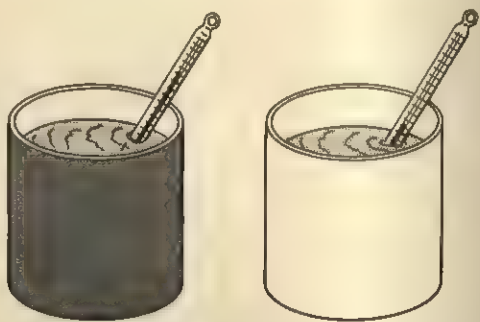


FIGURE 11–15.
A BLACK SURFACE ABSORBS RADIANT ENERGY MORE QUICKLY THAN A WHITE SURFACE.

3. *Unequal heating produces winds* · Obtain a large shoe box. Cut out a large rectangular hole in one side of the box and cover it with cellophane or Saran Wrap, taping the cellophane securely to the rest of the box. Cut two

holes about 1½ inches in diameter, one near each end of the box. Place the box, open end down, over a lighted candle so that the candle is directly over one of the cutout holes (Figure 11–16). Now put a lamp chimney over each hole.

(A rectangular aquarium, covered by a piece of cardboard with two holes in it, can be substituted for the shoe box.) Produce smoke by lighting a cigarette, a thick rope, or a tightly rolled piece of paper towel. Hold the smoking material directly over the chimney that does not have the candle under it. The smoke will be carried down the chimney, across the box, and up the other chimney. This movement occurs because the air above the candle is heated, expands, and becomes lighter. The warmer, lighter air is pushed up by the cooler, heavier air around it, causing a convection current. Winds on earth are formed in a very similar way.

4. *Wind is moving air* · Turn on an electric fan and have the children feel the "wind" blowing on their faces. Put a plant near the fan and let the children note the rustling of the leaves.

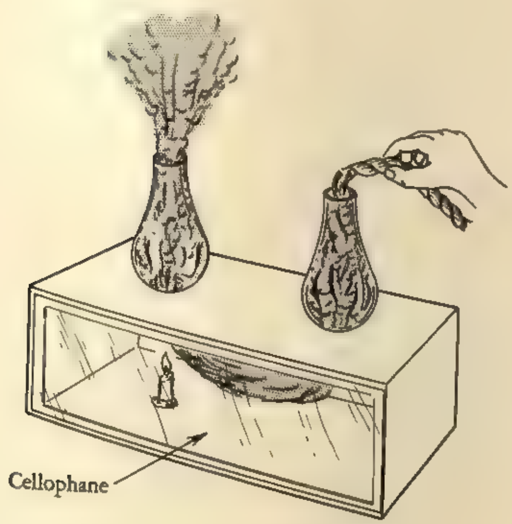


FIGURE 11–16.
WINDS ARE CAUSED BY CONVECTION CURRENTS OF AIR.

5. *The effect of the earth's rotation on the movement of winds* · Repeat Learning Activity 6 of "The Oceans" (p. 381). Point out that winds moving north or south in the northern hemisphere are deflected to the right (to the east), and winds moving north or south in the southern hemisphere are deflected to the left (to the west). Discuss the kind of wind movements the earth would have if it did not rotate.

6. *The major wind belts* · Draw on the chalkboard a circular globe of the earth and mark in the major wind belts (Figure 11–17, p. 384). Discuss how the belts are formed, accounting for the motion and direction of the winds in each belt.

7. *Jet streams* · Read about the path of the jet stream in the northern hemisphere. Trace this path on a globe of the world, during the winter and during the summer, and discuss the effects of this change in position on the earth's climate and weather. Consult the reports on studies made during the recent International Geophysical Year, announcing the discovery of new jet streams in the atmosphere of the earth.

8. *Monsoons* · Consult a map of the world and show why monsoons are found in India. Have the children explain why monsoons are found in such countries as Spain, Portugal, or Australia.

9. *Land and sea breezes* · Place some soil in a glass tumbler until the tumbler is half-filled. To another tumbler add water until it is the same level as the soil. Place a thermometer in each tumbler and keep the tumblers in a shady place until both thermometers read the same (Figure 11–18, p. 384). Now place both beakers in direct sunlight, and read the thermometers every 15 minutes for 1 hour. The temperature of the soil will be higher than the temperature of the water. Relate this difference in temperature to the formation of sea breezes and land breezes.

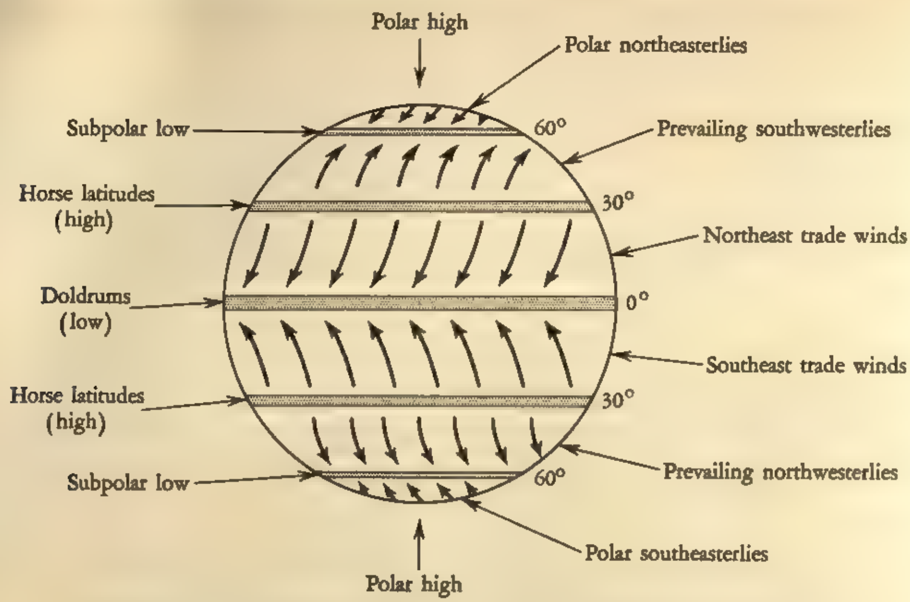


FIGURE 11–17. DIAGRAM OF THE MAJOR WIND BELTS ON EARTH.

WATER IN THE AIR

1. *Water evaporates* · Put some water in a dish and allow it to evaporate. Have the children make a list of phenomena they have seen about them that involve evaporation.

2. *Heat affects evaporation* · Put 10 drops of water in each of two pie tins that are the same size. Put one tin on the window sill where the sun can shine on it. Put the other tin in the coolest place in the classroom. The water will evaporate more quickly in the heated tin because the water molecules move faster, and thus more molecules can leave the water at one time.

3. *Surface area affects evaporation* · By using a measuring cup, put equal amounts of water in a pie tin, water tumbler, and narrow-neck medicine bottle. Set all three containers on a table, where conditions such as temperature and air currents will be the same for each container. The next day pour any water remaining in the containers back into the measuring cup, one at a time for each container. In each case measure the amount of water that remains. The most water will have evaporated from the pie tin, which has the largest surface area, because more water molecules were able to leave the water at one time.

4. *Wind affects evaporation* · Obtain two sponges the same size and wet them thoroughly. Make two spots of equal size and wetness on the chalkboard. Fan one of the spots vigorously with a cardboard. The moisture on the fanned spot will evaporate more quickly because the

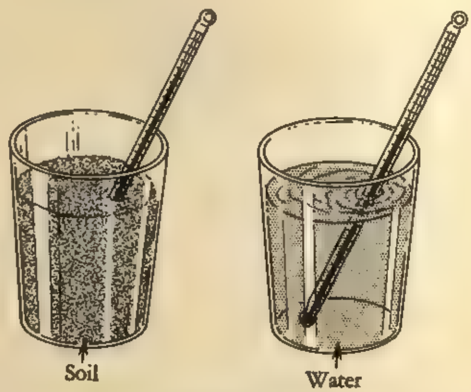


FIGURE 11–18.
SOIL HEATS UP MORE QUICKLY THAN WATER.

fanning blows away the saturated air above the spot and provides a fresh supply of unsaturated air.

5. *Humidity affects evaporation* · Compare the time it will take for the water in a wet cloth (or 10 drops of water in a pie tin) to evaporate on a dry day when the humidity is low and on a damp or rainy day when the humidity is high. The greater the humidity, the more water vapor there will be in the air, and the less opportunity there will be for more molecules of water to go off into the air.

6. *Evaporation is a cooling process* · Dip your forefinger into a tumbler of water. While keeping the wet forefinger and dry middle finger only a slight distance apart, blow on both fingers at the same time. As the water evaporates from the forefinger, the heat needed for evaporation is taken from the finger, leaving the finger cooler. The middle finger, which serves as a control, does not become cooler.

7. *Some liquids evaporate more quickly than others* · Have a child hold out both hands palm down. Put a drop of rubbing alcohol or duplicating fluid on the back of one hand and a drop of water on the back of the other hand. The rubbing alcohol will evaporate more quickly because its molecules are moving faster from the beginning at the same temperature. In addition, because the rubbing alcohol evaporates more quickly, it takes heat away from the hand more quickly, and the spot with the alcohol on it will feel cooler as well.

8. *Water vapor condenses* · Add water to a shiny tin can until the can is half filled. Then add ice cubes and stir. Soon a thin film of tiny droplets of water will form on the sides of the can, as the air containing water vapor is cooled and the molecules of water vapor move more slowly and come close enough together to become water again. The thin film will gradually form large droplets. In the summer the humidity may be so high that the water vapor will condense without ice cubes having to be added. In the winter the humidity may be so low that salt will have to be added to the cold water and ice cubes to get the water vapor to condense.

9. *Factors affecting condensation* · Point out that the same factors that affect the speed of evaporation will also affect the speed of condensation, but in reverse. Repeat Learning Activity 8 above in (1) a cold and warm location, (2) a windy and calm location, and (3) a dry and humid location.

10. *Dew and rain* · Repeat Learning Activity 8 above and relate the results to the formation of dew and rain. Find the dew point by slowly adding small pieces of ice to a tin can half-filled with water, stirring regularly with a thermometer. Measure the temperature at which a thin film of water appears on the sides of the can. Be careful not to breathe on the sides of the can when watching for dew to form. Otherwise the water vapor in your breath will condense on the cold sides of the can and produce inaccurate results.

11. *Make a fog* · Fill a clean, dry milk bottle (or any other bottle with a narrow neck) with very hot water, adding the water slowly to prevent the glass from cracking. Now pour out most of the water, leaving 1 or 2 inches in the bottom. Put an ice cube on the mouth of the bottle (Figure 11–19) and hold the bottle between you and the sunlight or the light of a lamp. A fog will form in the bottle as the warm, humid air is cooled by the ice cube and the cool air below the ice cube, and the water vapor condenses in tiny droplets that float in the air.

12. *How clouds are formed* · Obtain a gallon glass jug and a one-hole rubber that fits the mouth of the jug tightly. Insert a short piece of glass or plastic tubing into the hole of the stopper. Pour in enough water at room temperature to cover the bottom of the jug. Allow the water to stay in the jug for about 20 minutes to let some of the water evaporate into

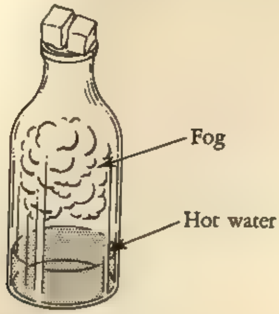


FIGURE 11–19.
CONDENSATION PRODUCES A FOG IN A BOTTLE.

the air inside the jug. Shake a little chalk dust into the jug. Now fit the stopper tightly into the jug and connect the rubber tubing of a bicycle pump securely to the glass tubing (Figure 11–20). Pump air into the jug for *no more than five or six strokes,* and then remove the stopper quickly. A cloud will form in the jug, which can best be seen by holding the jug between you and the sunlight or the light of a lamp. If the cloud does not form, repeat the experiment, adding a small amount of rubbing alcohol to the water this time.

If more air is pumped into the jug, the air inside the jug will be compressed. When the stopper is removed, the air will then expand. When a gas expands it becomes cooler. The air is cooled below the dew point by the sudden expansion, and the water vapor in the air condenses on the particles of chalk dust, forming a cloud. Point out that real clouds are formed the same way, being cooled because of the expansion of the warm, rising air.

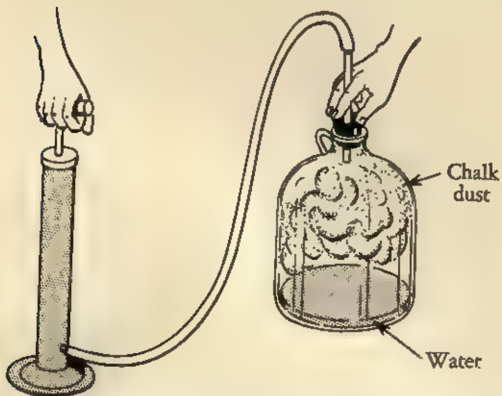


FIGURE 11–20.
CONDENSATION PRODUCES A CLOUD IN A JUG.

13. *Kinds of clouds* · Examine the sky daily for clouds and note the different forms of clouds. Draw relationships between the kinds of clouds and the kinds of weather they forecast. Collect pictures of the different kinds of clouds. Below each picture place an index card, telling how the clouds are formed, their characteristics, and the kind of weather they bring.

14. *Make frost, snow, sleet, and glaze* · Obtain a tall tin can and fill it with alternate layers of cracked ice and table salt. Make each ice layer twice as thick as the salt layer. Pack the mixture of ice and salt down firmly. Put two or three drops of water in the center of an index card, and place the tin can directly on top of the water (Figure 11–21). Some dew may form on the sides of the can and then freeze, but frost will also form as the temperature of the air beside the can falls to below freezing.

After the sides of the can are well covered with frost, remove the can from the index card. The drops of water will have frozen into ice. Point out that frost and snow are formed when water vapor condenses directly into ice crystals whereas sleet and glaze are formed when raindrops freeze.

15. *Examine snow crystals* · When it is snowing outside, catch some snowflakes on a soft,

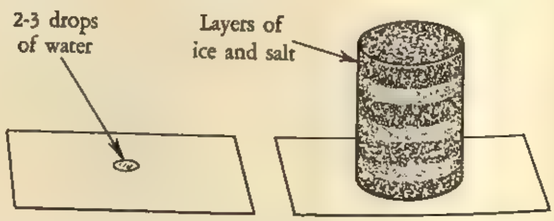


FIGURE 11–21.
FROST, SNOW, SLEET, AND GLAZE ARE FORMED AT TEMPERATURES THAT ARE BELOW FREEZING.

dark wool cloth. Try to capture small snowflakes because they are individual flakes while the larger snowflakes are usually clusters of smaller flakes. Examine the snowflakes with a magnifying glass. Note that all snowflakes have six sides, yet no two snowflakes are ever exactly the same.

16. *Examine hailstones* · During a hailstorm, collect some hailstones and quickly cut them in half. Note the layers of ice that have been formed. Each layer represents one complete movement up into cold air and back again into warmer air.

17. *Show the rain cycle* · Fill a Pyrex pot with water and heat the pot on a hot plate until the water is boiling vigorously. Fill a pie tin with ice cubes and, while using a pot holder or cotton glove, hold the pie tin about 6 inches above the pot (Figure 11–22). A miniature

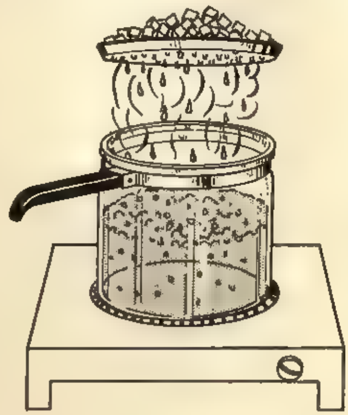


FIGURE 11–22. A MINIATURE WATER CYCLE.

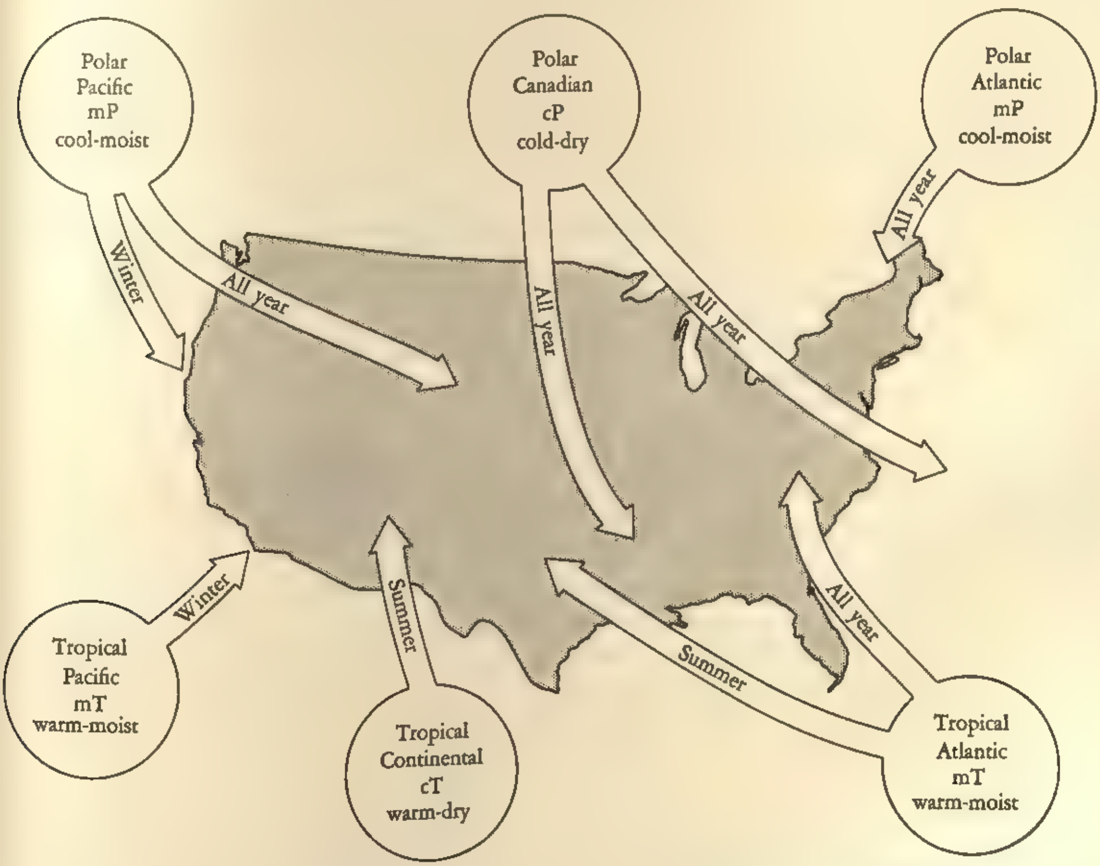


FIGURE 11–23. DIAGRAM OF THE MAJOR NORTH AMERICAN AIR MASSES.

water cycle will be produced as the water vapor from the boiling water is cooled by the cold bottom of the pie tin, causing droplets of water to condense on the bottom of the tin and then drop back into the water.

WEATHER CHANGES

1. *The North American air masses* · Draw on the chalkboard a relief map of North America, delineating the United States clearly. Chalk in the six air masses that affect the weather in the United States (Figure 11–23, p. 387). Identify these air masses as continental polar, maritime polar, continental tropical, and maritime tropical. Indicate whether the air masses are dry, moist, warm, or cold. Use arrows to indicate the paths of these air masses, and note whether they affect the United States all year or just during certain seasons.

2. *Cold and warm fronts* · Watch for the appearance of fronts, using the weather forecast as a guide. When a front begins to move in, keep a record of the weather conditions. Continue this record until the front has passed.

Draw on the chalkboard diagrams of the movement of a cold front and a warm front, showing the kinds of clouds and precipitation that are formed in each case (Figure 11–24).

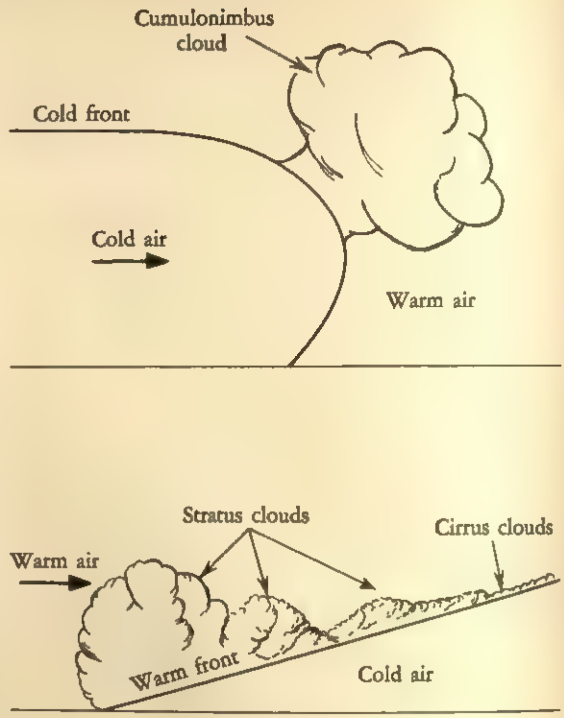


FIGURE 11–24.
DIAGRAM OF A COLD FRONT AND A WARM FRONT.

3. *The rotation of highs and lows* · Repeat Learning Activity 5 of "Winds" (p. 383), showing why the air in the northern hemisphere is deflected. Draw diagrams, using a series of arrows, showing why highs travel in a clockwise direction and lows in a counterclockwise direction in the northern hemisphere (Figure 11–25). Be sure to draw the arrows moving outward from the center and toward the right for the highs, and moving inward toward the center and to the right for the lows.

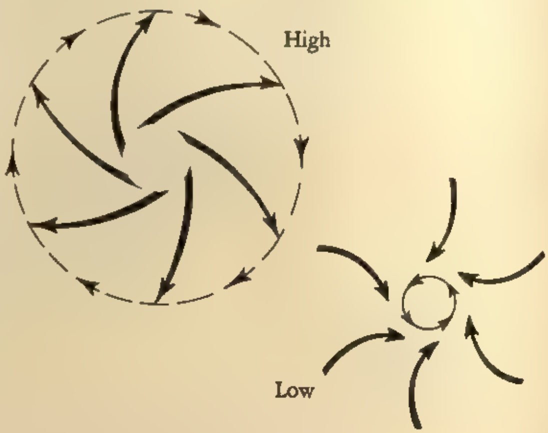


FIGURE 11–25.
HIGHS TRAVEL IN A CLOCKWISE DIRECTION, AND LOWS TRAVEL IN A COUNTERCLOCKWISE DIRECTION.

4. *Examine weather maps* · Have the children cut out weather maps from the newspaper for a period of 2 weeks. You can also obtain official weather maps by consulting your local weather station or by writing to the United States Weather Bureau at Washington 25, D.C. Examine the weather maps closely. Note the

presence and movement of cold and warm fronts across the country. List the kinds of weather changes the appearance of each front might bring, and check your list with the actual weather conditions that took place in your locality. Note the location of highs and lows on the weather map. Compare the kinds of weather found in those parts of the country that had highs with those that had lows.

5. *Hurricanes and tornadoes* · Have the children report how hurricanes are formed, trace the general path of hurricanes in the northern hemisphere, list the most destructive ones, compare their forward and circular speed, and describe the work of "hurricane hunters" in locating and charting the hurricanes.

Distinguish between hurricanes that form in the East in the late summer and fall, and tornadoes that form in the Midwest in the spring. Describe their similarities and differences, discuss the destruction and dangers each storm may cause, and list some safety precautions that should be taken.

6. *List unusual weather conditions* · Have the children bring in or make a collection of pictures of unusual weather conditions or unusual happenings that were influenced by the weather. Let the children try to trace the causes and events that produced these weather conditions.

PREDICTING THE WEATHER

1. *Make a barometer* · Obtain a milk bottle or a glass jar with a medium to narrow mouth. Cut out the dome-shaped end of a rubber balloon and stretch the rubber tightly across the mouth of the balloon, fastening the rubber sheet securely with a rubber band (Figure 11–26). Flatten both ends of a soda straw and cut one of the ends to a sharp point. Place rubber cement or glue on the flattened end of the straw and attach the flattened end to the middle of the rubber sheet. Cut a tiny piece of wood from a match and glue it at the edge of the rubber sheet so that the straw rests on top of the wood.

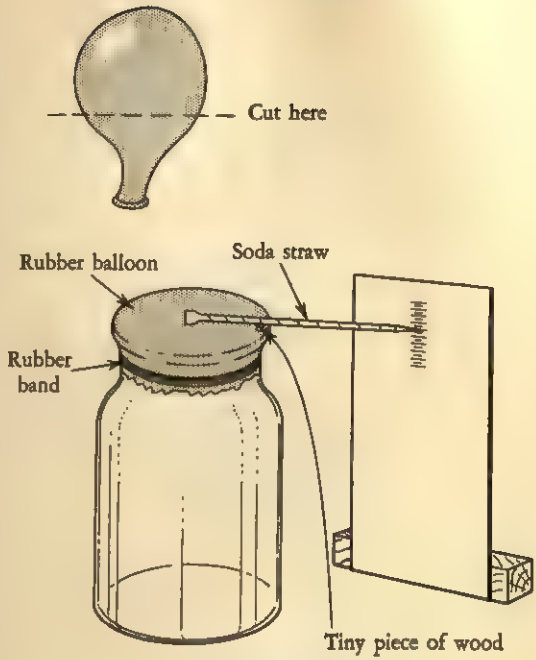


FIGURE 11–26.
A HOMEMADE BAROMETER.

When the air pressure in the room increases, the rubber sheet is pushed down, making the straw move up. When the air pressure in the room decreases, the greater air pressure inside the bottle now pushes the rubber sheet up, making the straw move down. A cardboard scale will help the children see the change in air pressure. Calibrate the marks on the cardboard scale with the readings on a standard barometer. Keep the barometer in a place as free from temperature changes as possible. Otherwise the air inside the bottle will expand and contract, pushing the rubber sheet in and out. Have the children take barometer readings each day for two weeks or a month and predict the weather on the basis of rising or falling air pressure.

2. *Make a thermometer* · Pour water that has been colored dark red with food coloring into a Pyrex flask until the flask is almost full

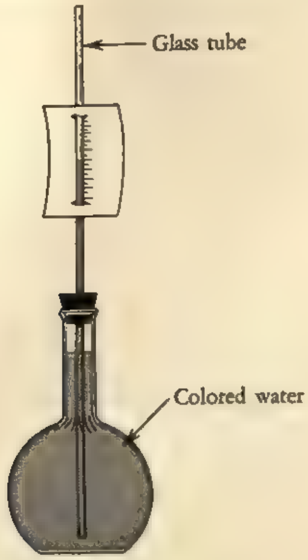


FIGURE 11–27.
A HOMEMADE THERMOMETER.

Insert a long glass or plastic tube in a one-hole rubber stopper and fit the stopper tightly into the mouth of the flask (Figure 11–27). The amount of water in the flask will have to be adjusted so that, when the stopper is inserted, the colored water will rise about one third to one half of the distance of the part of the tube above the stopper. Make two slits in an unlined index card and slide the card over the tube. Mark the original height of the water in the tube.

When the temperature of the room becomes warmer, the water is heated, expands, and rises up the tube. When the temperature drops, the water is cooled, contracts, and falls down the tube. Calibrate the marks on the scale of the index card with the readings on a standard thermometer. Have the children take daily readings outdoors on a standard thermometer (placed away from direct sunlight) for an extended period of time. Keep a record of these readings and make a chart showing the changes in temperature during the year.

3. *Make an anemometer* • Obtain two pieces of wood about 16 inches long, ¾ inch wide, and ¼ inch thick. Place one piece of wood on top of the other so that they form four right angles. At the center, where both pieces of wood meet, bore a hole just large enough for the glass part of a medicine dropper to pass through so that both pieces of wood will rest on the lip of the medicine dropper (Figure 11–28). Now use small screws or nails to fasten the two pieces of wood together, leaving the hole free. Obtain four paper cups, paint one cup red, and tack a cup horizontally to each end of the pieces of wood.

Hold the medicine dropper by the rubber bulb and place the top of the dropper in the tip of a gas flame or the flame of an alcohol lamp. Rotate the dropper slowly but steadily as you heat it, and continue heating until the tip of the dropper melts and the opening is closed. Make sure that the tip is completely closed before you remove it from the flame. Set the tip to one side and allow it to cool for at least 5 minutes.

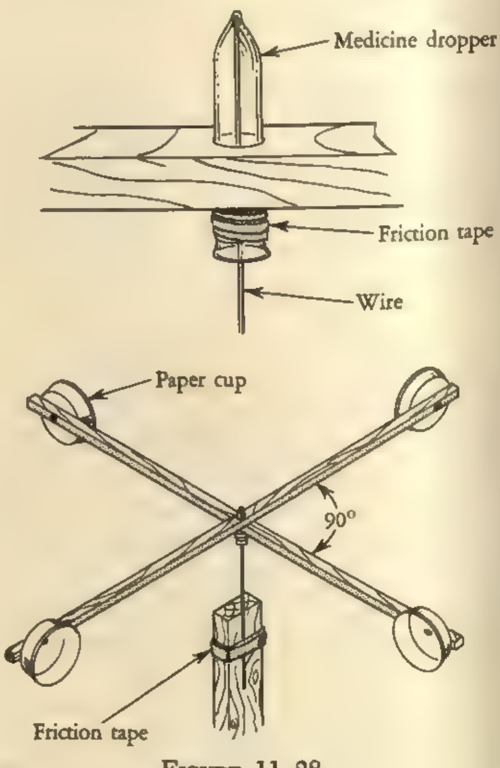


FIGURE 11–28.
A HOMEMADE ANEMOMETER.

Use wire cutters to cut a straight piece of wire from a coat hanger. File one end of the wire to a sharp point. Fasten the wire upright with friction tape to a sturdy piece of wood. Now remove the rubber bulb from the medicine dropper and insert the dropper into the center hole of the two fastened pieces of wood. Use friction tape above and below the hole, if necessary, to prevent the pieces of wood from slipping off the medicine dropper. Place the medicine dropper over the sharp point of the wire; the anemometer is now ready to operate with a minimum of friction.

To calibrate the anemometer, hold it outside the window of a moving car on a completely calm day when there is no traffic and the road is smooth and level. With the car moving at a steady speed of 5 miles an hour, use a watch with a second hand to count the number of turns the anemometer makes in 1 minute. The colored cup will make it easier for you to count the number of turns. Repeat the count at 10 miles an hour and also at 15 miles an hour. From these three counts you can make a graph that will enable you to calculate the wind speed at any time. (A quick but rough method for finding the wind speed is to count the number of turns in 1 minute and then divide by 10. The result will be the wind speed in miles per hour.)

4. *Make a weather vane* · Cut two large, identical arrows from a piece of heavy cardboard, making sure the tail is much larger than the head. Staple or paper clip the two arrows together at the edges of the head and the tail (Figure 11–29). Seal the tip of a medicine dropper, as described in Learning Activity 3 above. Place the arrow across the edge of a ruler and find the point where it best balances. Insert the medicine dropper between the two pieces of cardboard at this balancing point, and staple together the edges of the body of the arrow.

Use wire cutters to cut a straight piece of wire from a coat hanger, and file one end of the wire to a sharp point. Fasten the wire upright with friction tape to a sturdy piece of

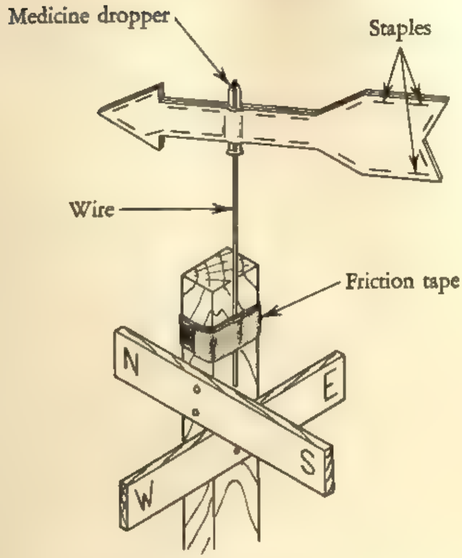


FIGURE 11–29.
A HOMEMADE WEATHER VANE.

wood, and place the medicine dropper over the sharp point of the wire. Use a compass when mounting the wind vane to fix the direction of the wind vane properly. If small strips of wood with the compass directions on them are nailed onto the vane, the children will be able to determine the wind direction more quickly and easily.

Because the tail is larger than the head, it will catch more wind. As a result, when the wind blows, the vane will swing around until it points into the wind toward the direction from which the wind is blowing.

5. *Make a wet-and-dry-bulb thermometer* · Obtain two chemical thermometers that have Fahrenheit scales on them and suspend them so that they hang side by side a few inches apart. If chemical thermometers are not available, use two identical wall thermometers, either suspended or strapped to a cardboard box with rubber bands.

Obtain a white, woven cotton shoelace or a piece of soft cotton cloth. Fit a section of the shoelace snugly around one of the thermometer bulbs and insert the end of the shoelace into

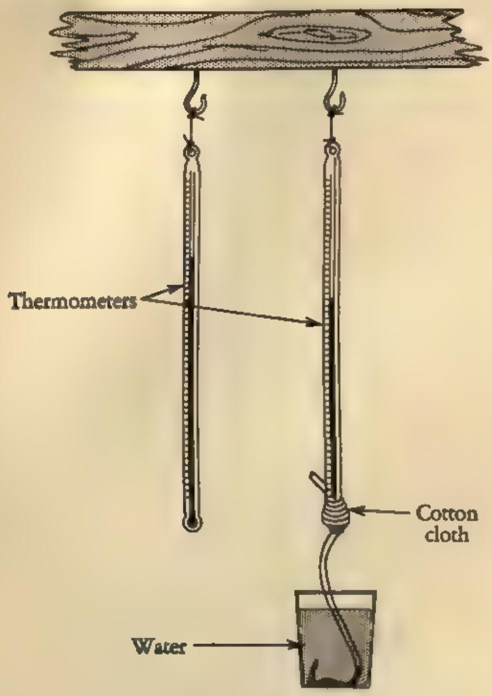


FIGURE 11–30.
A WET-AND-DRY-BULB THERMOMETER.

a tumbler of water (Figure 11–30). Now fan both thermometers, either by hand or with an electric fan, for a few minutes to blow away the air next to the cloth and keep it from being surrounded by a layer of saturated air.

To find the relative humidity, read both thermometers and find the difference between the two temperatures. Use this temperature difference and the temperature of the dry-bulb thermometer to find the relative humidity (in percentages) in Table 11–1.

6. *Make a hair hygrometer* · Obtain a strand of blond human hair about 8 inches long. Wash it thoroughly in hot, soapy water, rinse in cold water, and let it dry. Obtain a piece of two-by-four lumber about 12 inches long. While using a sharp razor blade, cut a piece about 1 inch long from a soda straw, making sure to preserve the cylindrical form of the soda straw. Obtain a broomstraw 4 or 5 inches long, and glue one end of the broomstraw to the piece of soda straw (Figure 11–31).

Obtain a long, narrow nail, put it through the piece of soda straw, and tape it into the center of the two-by-four lumber near one end. Fasten one end of the hair to a piece of cellophane tape about 2 inches long, and glue the other end of the hair to the piece of soda straw. When the glue has dried, turn the soda straw a few times to wrap the hair around the soda straw. Now attach the cellophane tape to the two-by-four lumber so that the hair is tight

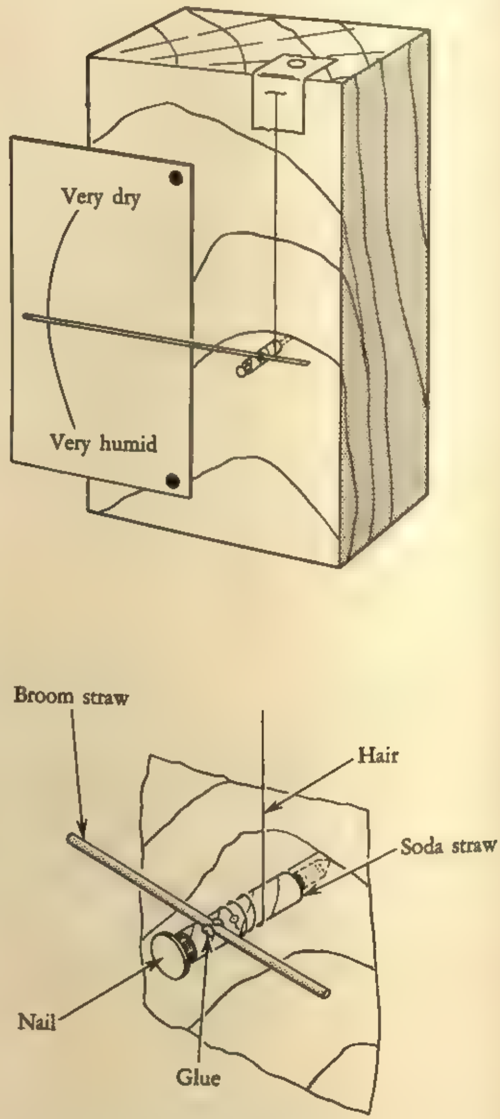


FIGURE 11–31.
A HOMEMADE HAIR HYGROMETER.

TABLE 11–1. Relative Humidity Index

DRY-BULB READING	DIFFERENCE BETWEEN WET- AND DRY-BULB READINGS																													
↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27			
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21	17	13	10	7	3							
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15	11	8	5	1						
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23	20	16	13	9	6	3						
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17	14	11	8	4	1					
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25	22	19	15	12	9	6	3					
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20	17	13	10	7	4	1				
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27	24	21	18	15	11	8	5	3				
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22	19	16	13	10	7	4	1			
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29	26	23	20	17	14	11	8	5	2			
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4			
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34	31	28	25	22	19	16	13	11	8	5			
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32	29	26	23	20	17	14	12	9	6			
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36	33	30	27	24	21	18	15	13	10	7			
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34	31	28	25	22	19	16	14	11	9			
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37	34	31	29	26	23	20	17	15	12	10			
80	96	81	87	83	79	76	72	68	64	61	57	54	51	47	44	42	38	35	32	29	27	24	21	18	16	13	11			
82	96	92	88	84	80	76	72	69	65	62	58	55	52	49	46	43	40	37	34	31	28	25	23	20	18	15	13	10		
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41	38	35	32	30	27	25	22	20	17	15	12		
86	96	92	88	85	81	77	74	70	67	63	60	57	54	51	48	45	42	39	37	34	31	29	26	24	21	19	17	14		
88	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43	41	38	35	33	30	28	25	23	21	18	16		
90	96	92	89	85	81	78	75	71	68	65	62	59	56	53	50	47	44	42	39	37	34	32	29	27	24	22	20	18		
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51	48	45	43	40	38	35	33	30	28	26	24	22	19		
94	96	93	89	86	82	79	75	72	69	66	63	60	57	54	52	49	46	44	41	39	36	34	32	29	27	25	23	21	19	17
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47	45	42	40	37	35	33	31	29	26	24	22	20	18
98	96	93	89	86	83	79	76	73	70	67	64	61	59	56	53	51	48	46	43	41	39	36	34	32	30	28	26	24	22	20
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54	52	49	47	44	42	40	37	35	33	31	29	27	25	23	21

and the broomstraw is in a horizontal position. Press the cellophane tape down firmly on top of the two-by-four lumber, inserting thumb tacks to prevent the tape from loosening. However, let the rest of the cellophane dangle loosely over the side to keep the hair from rubbing against the wood. Tack an index card to the two-by-four lumber on the side nearer to the broomstraw.

When the air is dry, the hair contracts and the broomstraw moves up. When the air is humid, the hair becomes moist and expands, making the broomstraw move down. Calibrate the hygrometer by putting it into a pail and covering the pail with a towel that has been soaked in very hot water. The relative humidity in the pail will quickly reach 100 percent, and the broomstraw will move down as the hair stretches. After 15 minutes remove the hygrometer and mark the position of the broom straw as 100 percent relative humidity. Allow some time for the pointer to move back to a normal position, and then calibrate other positions on the index card by using either a commercial hygrometer or a wet-and-dry-bulb thermometer.

7. *Make a rain gauge* · Obtain a large kitchen funnel and a glass jar whose mouth has exactly the same diameter as that of the rim of the funnel. Pour exactly 1 inch of water into the jar, using a ruler to get the exact depth of water (Figure 11–32). Pour this water into a long, narrow bottle, such as an olive jar. Place a strip of paper about ½ inch wide against the side of the narrow bottle, using strips of cellophane tape to hold the paper in place. With India ink, make a mark on the strip of

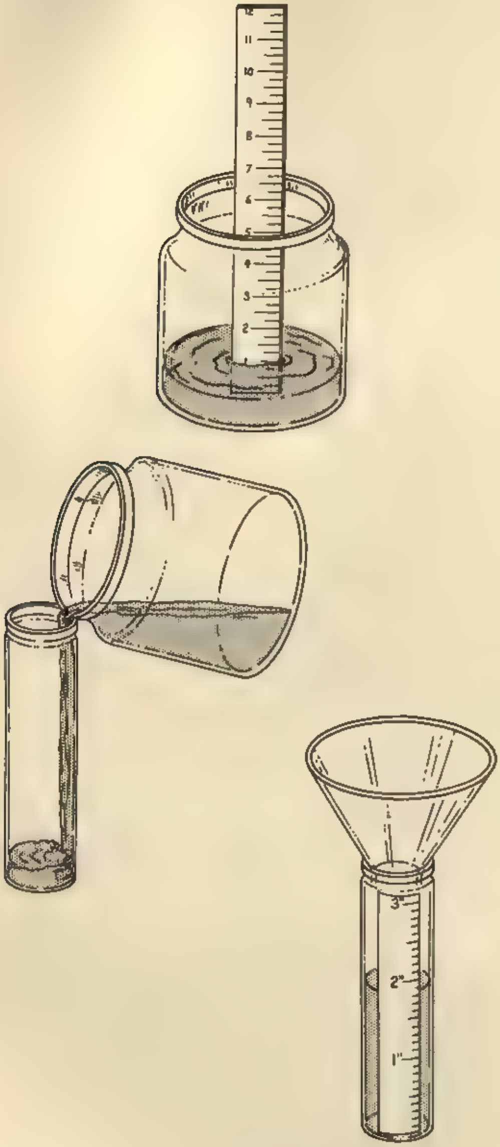


FIGURE 11–32.
A HOMEMADE RAIN GAUGE.

paper to indicate the inch of water, and label this mark "1 inch." Measure the distance from this mark to the bottom of the water in the jar, and use this distance to make additional marks on the paper, each mark accounting for another inch of water. Now divide the space between each mark into 10 smaller marks so that each smaller mark represents 1/10 inch of water. Empty the narrow bottle.

Put the narrow bottle in a large tin can so that the wind will not blow the bottle over during a rainstorm. Put the funnel in the neck of the narrow bottle, and place the tin can in an open area. The funnel will collect the rain and send it into the narrow bottle, where the amount of rainfall can be measured.

8. *Measure the amount of snowfall* · Immediately after a snowfall, select a spot where drifting or blowing of the snow has not taken place. Push a ruler or yardstick into the snow until the ruler touches the ground and read the number of inches of snow that have fallen. Divide this value by 10 to get a rough estimate of the number of inches of rain that would have fallen instead.

To convert the snowfall accurately into the equivalent rainfall, collect the falling snow in a tall coffee can and measure the depth with a ruler. Bring the can indoors, cover the top with a piece of cardboard, and allow the snow to melt slowly so that the amount of evaporation will be cut to a minimum. Now measure the melted snow to get the equivalent number of inches of rainfall.

9. *Set up a weather station* · Have the children set up their own weather station. Many of the instruments can be built by the children themselves. Weather maps can be obtained from the nearest weather bureau or from the Superintendent of Documents, Washington 25, D.C. The children can then post their own weather forecasts on the school bulletin board for the rest of the school to see and use. They might also post a small chart comparing the accuracy of their predictions with that of official weather forecasts.

10. *Keep a record of the weather* · Have the children keep a daily weather chart for a month. Make seven columns on a sheet of paper. In the first column put down the date and time the weather observations were made. The weather should be observed about the same time each day. In the other columns put down the following information: temperature out-

doors, air pressure, humidity, direction and speed of the wind, condition of the sky, and kind and amount of precipitation, if any. In the column describing the condition of the sky, make a small circle. Show how much of the sky is covered with clouds by blacking all, part, or none of the circle. While the children are keeping this chart, have them clip the weather forecast from the newspaper each day of the month. Then have the children compare the actual weather for each day with the weather predicted for that day, and see how often the weatherman was correct.

11. *The United States Weather Bureau* · Collect information and prepare a report on the services of the United States Weather Bureau. Information can be obtained from encyclopedias, science books, and the weather bureau itself. Many teachers combine a field trip to the local weather bureau with the trip to the airport.

12. *Man-made weather* · Have the children collect information about "seeding" clouds to produce rain and report upon the technique and effectiveness of this method. Do the same for devices that eliminate fog in airports.

13. *Weather sayings* · Many science textbooks and books on weather have weather sayings. Have the children collect a list of these sayings and decide which sayings have any scientific basis.

CLIMATE

1. *Factors controlling yearly temperature* · Consult maps of the United States and discuss what factors are involved in determining the yearly temperature of the city or town in which you live.

2. *Factors controlling yearly rainfall* · Consult maps of the United States and discuss what factors are involved in determining the yearly rainfall of the city or town in which you live.

3. *Climates in the United States* · Consult encyclopedias and other sources for maps and information about the different climates in the United States. Choose a representative selection of well-known cities, towns, or locations that illustrate the different kinds of climate. Compare the average rainfall, kinds of seasons, average yearly temperature, average summer and winter temperatures, and kinds of vegetation in these locations.

BIBLIOGRAPHY FOR "WATER, WEATHER, AND CLIMATE"

Antoine, Tex. *Wonders of the Weather.* New York: Dodd, 1962. 64 pp.

Bauer, Helen. *Water: Riches or Ruin.* New York: Doubleday, 1959. 121 pp.

Bell, Thelma Harrington. *Snow.* New York: Viking, 1954. 56 pp.

———. *Thunderstorm.* New York: Viking, 1960. 128 pp.

Bethers, Ray. *The Story of Rivers.* New York: Sterling, 1957. 47 pp.

Blough, Glenn O. *Water Appears and Disappears.* New York: Harper, 1959. 36 pp.

BONSALL, GEORGE. *The How and Why Book of Weather.* New York: Grosset, 1960. 48 pp.

CAMPBELL, ETHEL M. *The Wind . . . Nature's Great Voice.* Minneapolis, Minn.: Denison, 1959. 45 pp.

CARTER, KATHERINE. *The True Book of Oceans.* Chicago: Childrens, 1958. 47 pp.

COCANNOUER, JOSEPH A. *Water and the Cycle of Life.* New York: Devin, 1958. 143 pp.

EPSTEIN, SAM, AND BERYL EPSTEIN. *The First Book of the Ocean.* New York: Watts, 1961. 72 pp.

FISHER, JAMES. *The Wonderful World of Air.* New York: Doubleday, 1958. 70 pp.

FOLLETT, DWIGHT W. *Little Creek, Big River.* Chicago: Follett, 1961, 32 pp.

GALLANT, ROY A. *Exploring the Weather.* New York: Doubleday, 1957. 64 pp.

GIBSON, GERTRUDE HEVENER. *About Our Weather.* Chicago: Childrens, 1960. 32 pp.

GRAHAM, EDWARD H., AND WILLIAM R. VAN DERSAL. *Water for America: The Story of Water Conservation.* New York: Walck, 1956. 112 pp.

HASTINGS, EVELYN BELMONT. *About All Kinds of Days.* Chicago: Childrens, 1955. 24 pp.

HITTE, KATHRYN. *Hurricanes, Tornadoes, and Blizzards.* New York: Random, 1960. 82 pp.

IRVING, ROBERT (pseud. of Irving Adler). *Hurricanes and Twisters.* New York: Knopf, 1957. 144 pp.

JEANES, CHARLOTTE, AND RAYMOND CARLSON. *Water and the Thirsty Land.* Chicago: Follett, 1961. 28 pp.

LAIRD, CHARLES, AND RUTH LAIRD. *Weathercasting.* Englewood Cliffs, N.J.: Prentice-Hall, 1955. 163 pp.

MCGRATH, THOMAS. *About Clouds.* Chicago: Childrens, 1959. 32 pp.

NEWELL, HOMER E. *Window in the Sky.* New York: McGraw, 1959. 116 pp.

PARKER, BERTHA M. *Ask the Weatherman.* New York: Harper, 1958. 36 pp.

———. *Clouds, Rain, and Snow.* New York: Harper, 1959. 36 pp.

———. *Water.* New York: Harper, 1958. 36 pp.

———. *Water Supply and Sewage Disposal.* New York: Harper, 1958. 36 pp.

———. *Ways of the Weather.* New York: Harper, 1957. 36 pp.

PERRY, JOHN, AND JANE GREVERUS. *Exploring the River.* New York: McGraw, 1960. 203 pp.

PINE, TILLIE S., AND JOSEPH LEVINE. *Water All Around.* New York: McGraw, 1959. 48 pp.

SCHLOAT, G. WARREN, JR. *The Magic of Water.* New York: Scribner, 1955. 48 pp.

SCHNEIDER, HERMAN. *Everyday Weather and How It Works* (rev. ed.). New York: McGraw, 1961. 194 pp.

SLOANE, ERIC. *Eric Sloane's Weather Book.* Des Moines, Iowa: Meredith, 1952. 90 pp.

Spilhaus, Athelstane F. *Weathercraft.* New York: Viking, 1951. 64 pp.
Tannehill, Ivan Ray. *The Hurricane Hunters.* New York: Dodd, 1955. 271 pp.
White, Anne Terry. *All About Great Rivers of the World.* New York: Random, 1957. 150 pp.
Wyler, Rose. *The First Book of Weather.* New York: Watts, 1956. 63 pp.

CHAPTER

12 Air, Planes, *and* Space Travel

AIR

I. Where Air Is Found

A. Air is all around us.
  1. We live at the bottom of an ocean of air.
  2. Air occupies the space all around the earth to a height of hundreds of miles.

B. Air is also found in all the tiny spaces between particles of materials.
  1. Air is found in soil.
  2. Air is found in water.
  3. Air is found in such porous materials as sponges, bricks, wood, and bread.

II. The Composition of Air

A. Air is a mixture of many gases.

B. The two principal gases in the air are oxygen and nitrogen.

C. About one fifth of the air is oxygen (21 percent).
  1. Animals and plants need oxygen for breathing and digesting their food.
  2. Homes and factories need oxygen to burn their fuels.
  3. Oxygen is a very active gas and combines easily with many materials.

D. About four fifths of the air is nitrogen (78 percent).
  1. Nitrogen is the most abundant gas in the air.
  2. Nitrogen is not an active gas and will not help things burn or combine with materials easily, as oxygen does.
  3. If there were only oxygen in the air, without nitrogen, all burning would be very rapid and impossible to control.
  4. Nitrogen helps dilute the oxygen in the air and in this way controls burning.
  5. Nitrogen is needed by plants and animals as food, but they cannot use the nitrogen directly from the air.
  6. Man, and also certain plants, are able to change the nitrogen in the air into materials that plants and animals can use as food.

E. Together, oxygen and nitrogen make up almost 99 percent of the air.

F. The remaining 1 percent of the air is made up of carbon dioxide gas, hydrogen gas, and a group of rare and inactive gases known as helium, neon, argon, krypton, and xenon.

G. Although carbon dioxide is present in the air in very small quantities, it is a very important gas.
  1. Plants use carbon dioxide to make food,

which is used not only by the plants themselves but by animals as well.

2. Carbon dioxide is used in making "soda water" and "dry ice."
3. In baking bread and cake, the action of the yeast or baking powder in the dough releases bubbles of carbon dioxide gas, which expand and make the bread and cake rise.

H. Air also contains water in the form of an invisible gas, called **water vapor.**

1. The water vapor becomes part of the air by the evaporation of water from the oceans, lakes, rivers, and streams on the earth's surface.
2. The amount of water vapor in the air differs from day to day and from place to place.

I. Air also carries changing amounts of dust, pollen, plant spores, and waste gases given off by factories.

J. The amount of oxygen and carbon dioxide in the air remains the same because of the **carbon dioxide cycle.**

1. Green plants are always taking in carbon dioxide from the air to make food, and giving off oxygen as a waste product.
2. Man and animals breathe in oxygen to digest their food, and give off carbon dioxide as a waste product.

K. The amount of nitrogen in the air remains the same because of the **nitrogen cycle.**

1. Bacteria, called **nitrogen-fixing bacteria,** live in the roots of certain plants and change the nitrogen of the air, which the plants cannot use, into nitrogen materials that the plants can use to live and grow.
2. Animals eat the plants and give off waste materials containing nitrogen.
3. In the soil there are bacteria, called **nitrifying bacteria,** that change the nitrogen in these waste products into nitrogen materials that the plants can use.
4. When plants and animals die, the nitrogen in their bodies is changed by other bacteria, called **denitrifying bacteria,** into nitrogen gas, which goes off into the air.

L. The present composition of the air is much different from what it was when the earth was first formed.

1. At first there were large amounts of hydrogen gas and helium gas, but these gases were very light and went off into space.
2. When the earth was cooling, there most likely was just nitrogen, carbon dioxide, and water vapor in the air at first.
3. As the earth continued to cool, most of the water vapor condensed, leaving just nitrogen and carbon dioxide in the air.
4. When green land plants began to appear, the plants took in the carbon dioxide to make food and gave off oxygen as a waste product.
5. Over billions of years the plants reduced the amount of carbon dioxide in the air and increased the amount of oxygen until the present composition of these gases in the air was reached.
6. A certain amount of carbon dioxide was also removed as it dissolved in the waters of the earth and as it formed minerals called carbonates.

III. Air Pollution

A. Every day our air is being polluted by thousands of tons of gases and solids.

1. These materials are given off by smokestacks, chimneys, and exhaust pipes of cars.
2. Some of these materials can be annoying, and even dangerous to our health.
3. Continuous exposure to polluted air can cause lung diseases or aggravate existing ones.

B. The testing of atomic and hydrogen bombs adds dangerous radioactive particles to the air.

1. The harmfulness of these particles, when in the air, has not yet been fully established.
2. However, if these tests increase, enough

radioactive particles may accumulate to become highly dangerous.

C. Air pollution becomes a very serious problem when weather conditions in which the polluted air cannot be blown away are formed.
   1. These conditions occur when there is a layer of cold air next to the ground, and a layer of warm air lies on top of the cold air.
   2. The upper layer of warm air acts as a cover, and it stops the cold air from being carried away.
   3. This condition is called a **temperature inversion.**

D. In many parts of the United States, attempts are being made to control air pollution.
   1. In some communities factories are being made to install equipment that will remove the poisonous gases and smoke particles from their exhaust gases before these exhaust gases can escape into the air.
   2. In Los Angeles, California, all automobiles must install antismog devices, which trap or burn up the irritating gases that the exhaust pipes normally give off.

E. We must do everything we can to learn how to control air pollution.
   1. We must first identify which of the materials that pollute the air are dangerous.
   2. Then we must find out exactly how these materials get into the air.
   3. Finally, we must do everything we can to stop these materials from getting into the air.

IV. The Earth's Atmosphere

A. The ocean of air around the earth is called the **atmosphere.**
   1. The earth's pull, or force, of gravity holds the atmosphere to the earth's surface.
   2. The atmosphere is important because all animals and almost all plants need air to live.
   3. The atmosphere also acts as a protective blanket to cut down the heat of the sun's rays and to shield us from harmful rays that come from the sun and outer space.

B. Scientists divide the atmosphere into four principal layers: the **troposphere,** the **stratosphere,** the **ionosphere,** and the **exosphere.**

C. The troposphere is the lowest layer of the atmosphere.
   1. It extends upward to a height of 5 miles at the equator and 10 miles at the poles, with an average of about 7 miles in the areas between these two.
   2. Because almost all the water vapor in the air is in this layer, almost all weather conditions such as clouds and storms are found in the troposphere.
   3. Half of all the air in the atmosphere is in the lowest 3½ miles of the troposphere.

D. The stratosphere is the layer above the troposphere, and it extends upward from the top of the troposphere to a height of about 50 miles.
   1. The air is much thinner in the stratosphere.
   2. The stratosphere is clear and cloudless, and it does not have any weather conditions.

E. The third layer of the atmosphere, the ionosphere, extends upward from the top of the stratosphere to a height of about 400 to 500 miles.
   1. This layer is different from the other two layers.
   2. Powerful ultraviolet rays from the sun strike the particles of air in this layer and make the particles become electrically charged.
   3. These electrically charged particles of air are called **ions.**
   4. Man has found the ionosphere useful because it makes radio reception around the earth possible.

5. When radio waves travel out into space and reach the ionosphere, the radio waves bounce off the ions and are reflected back to a different part of the earth.
6. The Northern Lights (Aurora Borealis) come from the ionosphere.

F. The fourth layer, the exosphere, begins at the outer limit of the ionosphere and extends upward about 15,000 miles until it cannot be distinguished from outer space.

1. There is almost no air at all in the exosphere.
2. Man-made satellites have discovered areas of very intense radiation, called **radiation belts,** in the exosphere.
3. These radiation belts are known as the Van Allen radiation belts, and they are thought to be shaped like a doughnut within a doughnut.
4. The inner belt begins about 1400 miles above the earth and extends to about 3400 miles.
5. The outer belt begins about 8000 miles above the earth and extends to about 12,000 miles.

V. The Properties of Air

A. The gases that make up air are colorless, odorless, and tasteless.

B. Like all gases, air has no shape of its own, but it takes the shape of the container it fills.

C. Although air is invisible, it is real and takes up space.

D. Air has weight, and 1 cubic foot of air weighs about 1¼ ounces.

VI. Air Pressure

A. Air has pressure.

1. Air has weight, and anything that has weight pushes or presses against things.
2. We live at the bottom of an ocean of air hundreds of miles high.
3. This air presses down on the earth's surface and creates a pressure on the surface.
4. This pressure on the earth's surface is called **air pressure,** or **atmospheric pressure.**

B. As we go higher into the air, there is less air pressing down on us, and thus the air pressure becomes less.

C. Air presses in all directions—downward, upward, and sideways—on any exposed surface.

D. Air presses just as hard upward and sideways as it does downward.

1. Air presses on every square inch of surface of our bodies.
2. We do not feel this pressure because there is air inside our bodies that is pushing outward just as hard as the air outside our bodies is pushing inward.
3. The air pressure inside and outside our bodies is just the same.

E. Moving air exerts pressure.

1. When air moves, it pushes harder against things.
2. Wind is moving air.
3. The harder the wind blows, the greater pressure it will have.

VII. Measuring Air Pressure

A. At sea level the weight of the air pressing on 1 square inch of the earth's surface is about 15 pounds.

B. Scientists state this fact in another way, namely, that the pressure of the air at sea level is about 15 pounds per square inch.

C. The air pressure changes from day to day.

D. An instrument called a **barometer** is used to measure air pressure.

E. There are two kinds of barometers that are commonly used.

1. One contains a liquid, usually mercury, and is called a **mercury barometer.**
2. The other has no liquid in it, and is called an **aneroid barometer.**

F. The mercury barometer measures air pressure in terms of the number of inches of mercury standing in a glass tube.

1. The mercury barometer consists of a glass tube about 36 inches long and closed at one end.
2. The tube is first filled with mercury, then it is turned upside down in a dish that contains more mercury.
3. The mercury falls a few inches, but about 30 inches remains standing in the tube.
4. The pressure of the air on the mercury in the dish holds the mercury up in the glass tube.
5. Consequently, the air pressure of about 15 pounds per square inch holds up a column of mercury about 30 inches high.
6. When the air pressure becomes greater, the air pushes harder on the mercury in the dish and forces the mercury in the tube to rise.
7. When the air pressure becomes smaller, the air does not push as hard on the mercury in the dish, which allows the mercury in the tube to fall.
8. Measuring the height (in inches) of the mercury in the tube will give us the air pressure.

G. The aneroid barometer also measures the air pressure in inches of mercury, but it does not use mercury at all.
1. The aneroid barometer has a metal box in it with a thin, springy cover.
2. Most of the air inside the metal box has been taken out, which makes the cover very sensitive to changes in air pressure.
3. When the air pressure becomes greater, the air pushes harder on the cover so that the cover moves inward.
4. When the air pressure becomes smaller, the air does not push as hard on the mercury so that the cover moves outward.
5. This movement of the cover is carried by levers to a pointer that moves across a dial marked in inches.
6. In this way the air pressure may be read directly in inches of mercury.

H. An altimeter is an aneroid barometer that is used in planes to measure the height above sea level.
1. The higher up in the air we go, the less air pressure there is, and the lower the barometer will read.
2. Scientists have found that for every 1000 feet we go up into the air, the air pressure will fall about 1 inch.
3. The markings on the dial in an altimeter are changed so that, instead of giving the air pressure in inches of mercury, they give the number of feet above sea level.

VIII. Air Pressure Inside a Container

A. The air inside a container pushes, or exerts pressure, on the walls of the container.
1. Every material, including the gases in the air, is made up of tiny particles called molecules, which are moving rapidly.
2. When the fast-moving molecules hit the walls of a container, the molecules push against the walls and exert a pressure on them.

B. The air pressure in a closed container can be changed by adding or taking away more air.
1. If more air is added to the container, the air pressure inside becomes greater because more molecules of air are now striking and pushing against the walls of the container.
2. If air is taken away from the container, the air pressure inside becomes smaller because fewer molecules of air are now striking and pushing against the walls of the container.
3. If all the air is removed from a container, there will be no air pressure at all inside the container because there are no molecules of air inside to strike the walls.
4. An absence of all air inside a container is called a **vacuum**.
5. When only part of the air is removed from the container, there is only a partial vacuum present.

C. The air pressure inside a closed container

can be changed by making the size of the container larger or smaller.

1. If the size of the container is made larger, the air pressure inside becomes smaller because the air has spread out into a larger space so there are fewer molecules striking and pushing against each part of the container.
2. If the size of the container is made smaller, the air pressure inside becomes greater because the molecules of air have been squeezed into a smaller space, so there are more of them striking and pushing against each part of the container.

D. The air pressure inside a container can be changed by heating or cooling the container.

1. If the container is heated, the air pressure inside becomes greater because the molecules of air inside the container gain more energy and move faster so they strike and push harder against the walls of the container.
2. If the container is cooled, the air pressure inside the container becomes smaller because the molecules of air inside the container lose energy and move more slowly so they strike and push less strongly against the walls of the container.

IX. Some Effects of Decreasing the Air Pressure

A. Use of a soda straw depends upon decreasing the air pressure inside the straw.

1. When a straw is placed in a tumbler of soda, the soda rises up the straw to the level of the soda in the tumbler.
2. The soda in the straw does not rise any higher because the air pressure on the soda inside the straw and the air pressure on the soda outside the straw are equal.
3. When the movement of the cheek muscles sucks some air out of the straw, there is a partial vacuum inside the straw, and the air pressure inside the straw is smaller.
4. Normal or regular air pressure on the soda outside the straw is now greater than the air pressure on the soda inside the straw.
5. The outside air pressure, because it is greater, forces the soda up the straw and into the mouth.

B. To fill a medicine dropper depends upon decreasing the air pressure inside the dropper.

1. When the bulb is pressed, some of the air is forced out of the dropper, forming a partial vacuum and smaller air pressure inside the dropper.
2. The regular air pressure on the liquid outside the dropper is now greater than the air pressure on the liquid inside the dropper.
3. The outside air pressure, because it is greater, forces the liquid up the dropper.

C. Use of a suction cup depends upon decreasing the air pressure inside the cup.

1. When the suction cup is pressed against a surface, some of the air will be forced out of the cup, forming a partial vacuum and smaller air pressure inside the cup.
2. The outside air pressure is now greater and holds the cup firmly in place.
3. If the cup is moistened first, this moistening will make a tighter seal so that outside air cannot get inside the cup and remove the partial vacuum.

D. The operation of a vacuum cleaner depends upon decreasing the air pressure inside the cleaner.

1. An electrically driven fan drives air out of a compartment in the machine, forming a partial vacuum and smaller air pressure inside the compartment.
2. The outside air pressure is now greater than the air pressure inside the compartment, and the air rushes in through the nozzle, carrying dirt and lint with it.
3. The dirt and lint are caught by a bag or screen while the air passes out of the machine.

X. Some Effects of Increasing the Air Pressure

A. When a great deal of air is pumped into a container, the air is compressed and the air pressure inside the container is increased.
1. The molecules of air are squeezed, or compressed, very close together so that there are many more of them striking and pushing against the walls of the container.
2. The molecules are now striking with more force against the walls of the container so that the air pressure inside the container becomes greater.

B. Many appliances make use of the increased pressure of compressed air.

C. The air brake uses compressed air to stop trains, street cars, buses, and heavy trucks.
1. A motor-driven pump in the vehicle compresses the air, which is stored in a tank.
2. When the brakes are applied, the compressed air passes into a cylinder, where the compressed air exerts pressure against a piston.
3. The piston then forces the brake shoes tightly against a drum that is connected to the wheels, making the vehicle come to a stop.

D. The following items also make use of compressed air.
1. The caisson makes it possible for men to work under water.
2. The deep sea diver uses compressed air in his diving suit to go down hundreds of feet into water.
3. The submarine sinks when tanks let in seawater, and rises when compressed air forces the water out of the tanks.
4. Pneumatic drills and riveters operate by compressed air.
5. Automobile tires, footballs, basket balls, and volley balls have compressed air in them.
6. Many paint and garden sprays are operated by compressed air.

PLANES AND ROCKETS

I. The Forces Involved in Flying a Plane

A. When a plane is flying, there are four forces acting on it: **gravity, lift, thrust,** and **drag.**
1. The pull of the earth's gravity on the plane, which becomes the weight of the plane, is a downward force.
2. Lift is an upward force that acts against gravity, because of the action of the air on the wings, lifting the plane into the air and keeping the plane there while it is flying.
3. Thrust is the force that pulls the plane forward, and it is produced by a propeller or by a jet engine.
4. Drag is the resistance that the air offers because of friction when the plane moves through it, and it is a backward force that works against the thrust.

B. For a plane to fly, the lift must be greater than the force of gravity, and the thrust must be greater than the drag.

II. Producing Lift

A. The plane is lifted chiefly because of the flow of air passing over the wing.

B. A scientific principle, called **Bernoulli's principle,** explains why this lifting effect takes place.

C. Bernoulli's principle states that, when air moves faster across the top surface of a material than across the bottom surface, the pressure of the air pushing down on the top surface is smaller than the pressure

of the air pushing up on the bottom surface.

D. The shape of the wing is designed to make use of Bernoulli's principle.
   1. The front edge of the wing is thicker than the back edge, and the upper surface of the wing is curved whereas the under surface is straight.
   2. When the wing moves through the air, some of the air flows over the wing and some flows under the wing.
   3. Because the upper surface of the wing is curved, the air that flows over the upper surface must travel a longer distance than the air that flows along the bottom surface.
   4. However, scientific tests show that all of the air flowing over and under the wing reaches the end of the wing at the same time.
   5. Consequently, the air flowing over the curved, top surface of the wing must move faster than the air flowing along the shorter, bottom surface to reach the end of the wing at the same time.
   6. According to Bernoulli's principle, because the air is moving faster across the top surface of the wing than across the bottom surface, the air pressure pushing down on the top surface is smaller than the air pressure pushing up on the bottom surface.
   7. The greater air pressure underneath the wing pushes up on the wing and produces lift.

E. The greater the wingspread, the more air passes over and under the wing, and the greater the lift will be.

F. The faster the plane moves, the faster the air will flow over the wing, the smaller the air pressure pushing down on top of the wing will be, and the greater the lift will become.

G. The wing's angle of attack also helps lift the plane.
   1. The wing is set so that it tilts a little, and meets the air at a small slant, or angle.
   2. This slant, or angle, is called the angle of attack.
   3. Because the wing is slanted, the air strikes the underside of the wing and pushes up on it.
   4. When greater lift is needed, the wing can be made to slant even more, so the air will push up harder on the wing.

III. PRODUCING THRUST

A. Thrust is the force that pulls the plane forward and, at the same time, makes air flow above and below the wings.

B. A scientific principle, called **Newton's third law of motion,** makes thrust possible.

C. Newton's third law of motion states that, for every action, there is an equal but opposite reaction.

D. Some planes use a propeller to produce thrust.
   1. The propeller is made to turn at a very high speed by an engine that uses gasoline as fuel.
   2. The blades of the propeller are shaped in such a way that, when they turn, they push the air backward.
   3. As the air pushes backward, there is an equal but opposite forward push, or thrust, on the propeller, which drives the plane forward.
   4. The propeller bores into the air somewhat like a screw going into wood or a boat propeller going through water.

E. Jet planes get their thrust from jet engines.
   1. Jet engines are simpler than the engines in propeller-driven planes.
   2. The jet engine is a hollow cylinder that is open at both ends.
   3. Air that enters the front end of the cylinder is compressed, and then a fuel such as kerosene is sprayed into the cylinder.
   4. The mixture of kerosene and compressed air burns with intense heat, giving off hot gases that expand and shoot out of the rear of the cylinder with great force and speed.

5. As the hot gases shoot out with a backward force, we get an equal but opposite force, or thrust, that moves the plane forward at great speed.
6. The faster the fuel burns, the greater the backward push of the hot escaping gases, and the greater will be the forward push on the plane.

F. The three most common types of jet engines used in recent years are the ramjet engine, the turbojet engine, and the turboprop engine.

G. The ramjet engine is the simplest type of jet engine and has no moving parts.
1. It is a hollow tube, with nozzles inside to spray the fuel.
2. When the ramjet travels forward at great speed, air is packed or "rammed" into the front of the engine.
3. The "ramming" of the air into the engine helps to compress it.
4. Fuel is sprayed into the compressed air by the nozzles, and burns.
5. The hot gases expand and rush out through the rear of the engine with great speed.
6. These hot gases, escaping from the rear of the engine, produce the forward thrust needed to move the plane.
7. The ramjet plane cannot start from the ground, but it must be moving at high speed to "ram" air into the engine.
8. Usually a ramjet plane is carried into the air under another plane, which cuts the ramjet loose when the speed is high enough.

H. The turbojet engine is the engine used most often by commercial and military planes.
1. The turbojet engine has three main parts: a compressor, a combustion chamber, and a turbine.
2. The compressor compresses the air that enters the engine, and feeds the compressed air to the combustion chamber.
3. In the combustion chamber a fuel such as kerosene is sprayed into the compressed air.
4. The mixture of kerosene and compressed air burns, giving off hot gases that expand and shoot out of the rear of the engine.
5. Before the gases can leave the engine, they must first turn the blades of the turbine.
6. A shaft connects the turbine to the compressor so that the escaping gases turn the turbine, which then operates the compressor.
7. When the turbojet plane is on the ground, a small engine starts the shaft turning and operates the compressor.
8. After the plane has reached a high enough speed, the jet engine itself takes over and operates the turbine and the compressor.

I. The turboprop engine is just like a turbojet engine except that it has a propeller in front of it.
1. The propeller is attached to the same shaft that connects the turbine and compressor.
2. In this way both the propeller and the escaping gases from the rear of the engine produce the thrust that moves the turboprop plane forward.
3. The turboprop plane operates very well at low speeds or low altitudes because of the added thrust from the propeller, but the turbojet plane does not.

IV. Reducing Drag

A. The friction of the air rubbing against the moving plane causes the air to resist the plane's forward motion, and slows down the plane.

B. At high speeds this air resistance, or drag, can become very great and slow down the plane.

C. To overcome drag, the plane is streamlined.
1. Streamlining means that the plane is designed in such a way that the air flows past the plane smoothly.
2. Scientists copy the streamlined shapes of

fish, birds, and tear drops when designing planes.
3. Cars and trains are also streamlined.

V. The Parts of the Plane and Their Functions

A. The **fuselage** is the body of the plane, and it carries the cargo, passengers, crew, and fuel.
B. The **engine** provides the power or thrust to move the plane forward by turning a propeller or, if it is a jet plane, by the action of the jet engine itself.
C. The **wings** are attached to the sides of the fuselage and provide the lift for the plane.
D. The **ailerons** are long, narrow movable flaps located near the wing tips at the rear of the wings.
   1. The ailerons move up and down, but, when one aileron moves up, the other must move down.
   2. The ailerons are used to steer the plane to the right or left.
E. There are also movable flaps at the rear of the wings, between the ailerons and fuselage, that help the plane take off and land.
F. The **tail** of the plane has many parts to it.
   1. The **fin**, or **vertical stabilizer**, does not move, and it helps keep the plane flying straight.
   2. A movable **rudder** is connected to the back of the fin, and it helps turn the plane to the right or left.
   3. The **horizontal stabilizers** on each side of the fin keep the plane from rising and falling while the plane is flying level.
   4. The **elevators** are movable flaps connected to the horizontal stabilizers, and both elevators move up or down at the same time to make the plane climb or dive.
G. The **landing gear** is underneath the plane, and it is used for taking off and landing.
   1. **Wheels** are used for planes that take off or land on hard surfaces.
   2. In most planes the wheels fold up into the body of the plane after the plane is off the ground, to cut down the drag while the plane is flying.
   3. Long, hollow floats, called **pontoons**, are used for planes that take off or land in water.
   4. **Skis** are used for planes that take off or land in snow.

VI. Airplane Instruments

A. The **radio altimeter** measures how high the plane is above the ground.
   1. It sends out a radio beam that hits the ground and bounces back.
   2. The time it takes for the beam to reach the ground and return to the plane is changed by the radio altimeter into feet above the ground.
B. The **compass** helps the pilot keep the plane flying in the right direction.
   1. Many small planes use a magnetic compass, and the pilots have to make corrections constantly because of irregularities in the earth's magnetic field.
   2. Large planes use a **gyrocompass**, with a spinning gyroscope wheel inside it, that always points to the desired direction throughout the flight.
C. The **air-speed indicator** shows the flying speed of the plane, but the actual speed will be smaller if the plane is heading into the wind, or greater if the wind is at the plane's tail.
D. The **bank indicator** lets the pilot know if the plane is tilting, or banking, properly when making a turn.
E. The **turn indicator** lets the pilot know if the plane is turning properly and how fast the turn is being made.
F. The **fuel gauge** shows the amount of fuel in the tank.
G. **Pressure gauges** show the oil pressure, fuel pressure, and cabin pressure.
H. **Temperature gauges** show the temperatures in different parts of the engines.
I. The **tachometer** shows how fast the shaft in each engine is turning.

J. A **two-way radio** helps the pilot stay on course when the plane is flying, and gives him instructions for taking off or landing.

K. An **automatic pilot**, which uses spinning gyroscope wheels, takes over the controls and keeps the plane on the course set by the pilot.

VII. Controlling the Plane in Flight

A. *The takeoff*

1. To take off, a plane must be going fast enough to rise in the air.
2. Planes take off into the wind because the wind will make the air flow faster over the surface of the wings and help make the lift greater.
3. This kind of takeoff means that the plane will not have to travel as far down the runway before taking off.
4. The plane goes faster and faster until it reaches its take-off speed, where the lift is great enough to make the plane rise.
5. The pilot then pulls the control wheel toward him just a little, which makes the elevators in the tail tilt up a little.
6. The rushing air strikes these elevators, which forces the tail down.
7. This action swings the nose of the plane up, and the plane takes off into the air.
8. As the plane rises, the landing gear is pulled back into the plane.
9. The plane climbs until it reaches the height the pilot wants to fly.
10. The elevators are then lowered until they are even again, and the plane flies level.

B. *Climbing and diving*

1. To climb, the pilot pushes the control wheels toward him, making the elevators in the tail tilt up.
2. The air strikes these elevators and forces the tail down, which swings the nose of the plane up so that the plane climbs.
3. The plane needs more power when it is climbing and moving against gravity so that the engines are given more fuel and consequently speed up.
4. To dive, the pilot pushes the control wheel away from him, making the elevators tilt down.
5. The air striking the elevators forces the tail up, which swings the nose down so that the plane dives.
6. The plane needs less power when it is diving, because gravity helps pull the plane down, so the engines are given less fuel and consequently slow down.

C. *Turning to the right and left*

1. To make a turn the pilot must tilt, or bank, the plane's wings in the direction he wants to turn, in much the same way that we tilt a bicycle when going around a curve.
2. To turn to the right, the pilot turns the control wheel to the right.
3. This turning of the wheel makes the right aileron in the wing go up, and the left aileron go down.
4. When the rushing air strikes the ailerons, it makes the right wing fall and the left wing rise.
5. This action makes the plane roll on its side and turn, or bank, to the right.
6. At the same time, the pilot pushes the left foot pedal and makes the rudder in the tail swing to the left.
7. The rushing air strikes the rudder and makes the nose of the plane move to the right.
8. This action helps the plane turn to the right and also helps prevent the plane from yawing, or skidding sidewise, in the turn.
9. To make a left turn, the pilot turns the control wheel to the left, making the right aileron go down and the left aileron go up.
10. Air strikes the ailerons, making the right wing rise and the left wing fall, and the plane turns, or banks, to the left.
11. At the same time, the pilot pushes the right foot pedal, making the rudder swing to the right.
12. Air strikes the rudder and makes the nose of the plane move to the left.

D. *Landing*

1. To land, the pilot dives by making the elevators tilt down.
2. As the plane dives, the pilot lowers the landing gear.
3. The plane moves into the wind so that the resistance of the air striking the plane will cut down the landing speed.
4. When the plane nears the runway, the pilot moves the elevators up to make a level landing.
5. When the plane is ready to land, the pilot lowers the flaps attached to the wings between the ailerons and the fuselage.
6. These flaps act as air brakes.

VIII. The Sound Barrier

A. The speed of sound is about 1100 feet per second, or about 760 miles per hour.

B. As the plane moves through the air, it produces sound, which travels out in waves.

C. These sound waves are compressed, and then expanded, as they travel.

D. When a plane travels slower than the speed of sound, the sound waves travel away from the plane faster than the plane is moving.

E. But, when a plane travels at the speed of sound, these compressed sound waves cannot travel away from the plane because both the plane and the waves are now traveling at the same speed.

F. The sound waves then pile up in front of the plane and form a huge wall of air, called the **sound barrier.**

G. This wall of piled-up, compressed air pushes along at the speed of sound and becomes a shock wave.

1. The pressure of this shock wave is so great that it can rip the wings off an ordinary plane.
2. At the same time the shock wave produces a loud noise, like a giant clap of thunder, so strong that it can rattle—even break—dishes and windows.

H. When the plane breaks the sound barrier and travels faster than the speed of sound, the sound waves no longer affect the plane because they are now left behind.

I. Planes that fly through, or break, the sound barrier are designed in a special way.

1. The nose of the plane is made longer and more needlelike.
2. The wings are thin, with sharp edges in front.
3. The wings also sweep back at an angle so that they look like large triangles.
4. Wings shaped in this manner make it easier for the plane to break through the sound barrier.

IX. The Heat Barrier

A. The friction of the air as it moves across the plane produces heat.

B. The faster the plane moves, the greater the air friction, and the more heat is produced.

C. The temperature at which the heat weakens and melts the parts of the plane is called the **heat barrier.**

D. The kinds of materials that make up the plane are more important in overcoming the heat barrier than the speed of the plane itself.

E. Scientists are trying to discover new materials, to be used in building planes and rockets, that will help them break the heat barrier.

X. The Helicopter

A. The helicopter has a large wing or rotor that spins above the plane.

B. As the rotor spins rapidly, it provides both the lift to raise the helicopter in the air and the thrust to move the helicopter forward.

C. By changing the tilt of the rotor, the helicopter can go straight up or down, forward or backward, sideways, or just hover in the air.

D. As the rotor spins, it tends to twist the rest of the helicopter.
  1. To stop this twisting effect, a smaller propeller or rotor is placed on the helicopter's tail and spins in the opposite direction to that of the large rotor.
  2. The smaller rotor also is used to steer the helicopter.

E. The helicopter does not travel very fast, but it has many valuable uses.
  1. It can be used to rescue persons at sea or remove injured persons from spots that are hard to reach.
  2. It can carry mail or persons for short distances to airports.
  3. It can patrol the waterfront or supervise automobile traffic on highways.
  4. It can be used to spot forest fires or persons lost in a forest.
  5. It can be used to spray insecticide on crops.

XI. Rockets

A. Rocket engines, like jet engines, make use of Newton's third law of motion that is concerned with action and reaction.

B. Like the jet engine, burning fuels in the rocket produce hot, expanding gases that blast from the tail of the rocket and give it the thrust required to go up into space.

C. The main difference between the rocket and the jet is in the source of oxygen needed to burn the fuel.
  1. A jet gets its oxygen from the air.
  2. A rocket carries its own oxygen supply, either as liquid oxygen or as a chemical that contains oxygen and gives it up readily.
  3. The chemical that contains oxygen may be a liquid or a solid.

D. Because a rocket carries its own oxygen, it can travel in space where there is little or no air.

E. The simplest, and oldest known, rockets are the **solid fuel** rockets.
  1. The solid fuel is really a mixture of a fuel and a chemical that contains oxygen.
  2. These rockets are used to help launch planes, and they are also used in fireworks and as signal rockets.

F. High altitude rockets are **liquid fuel** rockets.
  1. These rockets use both a liquid fuel and liquid oxygen.
  2. These two liquids are stored in separate tanks in the rocket, and are pumped into the combustion or burning chamber at the same time.

G. High altitude rockets do not have wings because they travel where there is no air to provide lift for the wings.

H. The **intercontinental ballistic missile** is a high altitude rocket.
  1. In the head of the rocket there is an atomic or hydrogen bomb.
  2. The missile can travel hundreds of miles into outer space, and then go back to earth thousands of miles away from the point where it was launched.

I. Scientists have found that they can get rockets to travel faster and farther when they connect more than one rocket, or stage, together.

J. A **three-stage rocket** has three rockets, one mounted on top of the other, each with its own fuel and combustion chamber.
  1. The first stage is the largest rocket, at the bottom.
  2. When the first stage is fired, it pushes up all three rockets.
  3. The three-stage rocket climbs until all the fuel in the first stage is used up.
  4. Then the first stage drops off, and the second stage is fired.
  5. The second and third stage together climb faster and higher until all the fuel in the second stage is used up.
  6. Then the second stage falls off, and the third stage is fired.
  7. The third stage holds the instruments, and even men, in it.
  8. The third stage climbs even higher and faster, and then either falls back to earth or goes into orbit around the earth as a satellite.

SPACE TRAVEL

I. Early Space Exploration with Rockets

A. During World War II and afterward, scientists made great advances in the study of rockets.

B. They improved the rocket design and were able to send rockets up to greater heights than had ever before been reached.

C. Rockets containing instruments, cameras, and recording devices were sent up as high as 250 miles.

D. However, these rockets were fired almost straight up, reached their greatest height in minutes, and then fell back to earth.

1. These rockets were at different levels of the air for only a very short time, and very little could be found out about space during that time.
2. Also, because the rockets went straight up, only the space above just one part of the earth's surface could be explored.

II. Man-Made Satellites

A. After scientists had experimented with rockets that went straight up, they decided to try something different.

B. They tried the idea of a rocket going high above the earth's surface and staying there for some time.

C. The only way this could be done was to make the rocket travel around the earth in an orbit, just as the moon makes an orbit around the earth.

D. Because the moon is called a **satellite** (a heavenly body revolving around a planet), this orbiting rocket was called a satellite too.

E. On October 4, 1957, the Soviet Union sent up Sputnik I, the first earth satellite around the earth.

F. A month later the Russians sent up Sputnik II, with a dog in it.

G. On January 31, 1958, the United States sent up its first satellite, the Explorer I.

III. Getting a Satellite into Orbit

A. To get a satellite into orbit, the satellite must first be sent hundreds of miles up into the air at a very high speed, and then it must be given the proper speed and direction to go sideways in an orbit around the earth.

B. To accomplish orbiting, three or four rockets are put together, one on top of the other, with the biggest and heaviest rocket at the bottom.

1. Each rocket is called a stage, and each stage has its own fuel and combustion chamber.
2. The stages do not all go off together, but they are fired one after the other.
3. When one stage uses up its fuel, it drops off, and the next stage takes over.

C. The satellite is on top of the last rocket, and it contains the instruments and astronauts.

1. The satellite is the smallest part of the rocket.
2. It has a nose cone over it to protect it from the heat produced by friction as the rocket moves through the air.
3. The satellite and its instruments are often called the "pay load" of the rocket.

D. When the first stage of a three-stage rocket is fired, the rocket goes straight into the air.

1. The rocket goes up slowly at first because it must overcome the pull of gravity, and also because the heavier air in the lower atmosphere would batter the rocket into pieces if the rocket were traveling at high speed.
2. The rocket begins to pick up speed and then is made to tilt so that it travels at an angle.
3. By the time the rocket is in the outer limits of the stratosphere, the fuel in the first stage burns out, and the stage drops off.

E. The second stage takes over and lifts the rocket higher and faster into space.
   1. The rocket keeps tilting until its path is much flatter and more in a line with the surface of the earth.
   2. The fuel in the second stage burns out at a point just before the satellite goes into orbit, and the stage drops off.

F. The third stage takes over and puts the satellite into orbit.
   1. When the rocket reaches the proper height, the third stage fires and tilts the satellite in as close a path parallel to the earth's surface as the instruments will allow.
   2. The third stage drops off, leaving the satellite in orbit.
   3. The protective nose cone drops off the satellite at the same time.

G. Rockets are often launched toward the east because the east is the direction of the earth's rotation.
   1. The earth rotates on its axis at a speed of about 1000 miles per hour.
   2. The earth's speed gives the rocket an extra push which helps the rocket reach the speed it needs to go into orbit.

IV. Keeping the Satellite in Orbit

A. The speeding satellite stays in orbit around the earth because there are two forces acting on it.

B. One force is the earth's **pull of gravity** on the satellite, which tries to pull the satellite down to the earth.

C. The second force is due to **inertia**, which tries to make the satellite move in a straight line out into space.
   1. The action of inertia is based upon a scientific principle, called Newton's first law of motion.
   2. This law states that a body at rest tends to stay at rest and a body in motion tends to continue in motion **in a straight line** at the same speed, unless some outside force acts on the body to change this condition.

D. Both forces act against each other.
   1. If only gravity were acting on the satellite, the satellite would fall to the earth.
   2. If only inertia were acting on the satellite, the satellite would fly off into space in a straight line.

E. The third stage of the rocket gives the satellite exactly the proper sideways speed, called the **orbital velocity**, so that the force of gravity and the force of inertia balance each other.

F. As a result, the satellite neither falls to earth nor flies off into space, but instead it moves in an orbit **around** the earth.

V. The Path of the Satellite

A. Most man-made satellites travel in an elliptical, or oval-shaped, orbit rather than a circular orbit.

B. This kind of orbit is most common because it is very hard to launch a satellite at just the right angle and speed to get a perfect, circular orbit.

C. Some satellites are purposely made to travel in an elliptical orbit so that they can give information about conditions in space both near the earth and much farther away.

D. In an elliptical orbit the satellite comes closer to the earth at one part of its trip and then goes farther away at another part of its trip.
   1. The point in the orbit where the satellite is nearest the earth is called the **perigee.**
   2. The point where the satellite is farthest away from the earth is called the **apogee.**

E. The satellite needs a sideways speed, called **orbital velocity**, to stay in orbit around the earth.
   1. The farther the orbit is away from the earth, the smaller the earth's pull of gravity on the satellite becomes, and the less sideways speed the satellite needs.
   2. To travel in an orbit at a height of 300 miles, a satellite needs an orbital velocity of about 18,000 miles per hour.

3. At 2000 miles the orbital velocity must be about 14,400 miles per hour.
4. At 10,000 miles the orbital velocity must be about 7200 miles per hour.
5. At 22,000 miles the orbital velocity must be about 6800 miles per hour, and the satellite would travel around the earth once every 24 hours.
6. At 22,000 miles such a satellite would seem to be stationary in the sky, if it traveled in a counterclockwise direction (west to east) just as the earth does.

F. Eventually, most satellites orbiting the earth fall back to earth.
1. At the perigee of its orbit, the heavier air slows the satellite a little, especially if the satellite started with a perigee fairly close to earth.
2. Each time the satellite enters its perigee, it is slowed down more so that its orbit gets rounder and smaller, and the earth's gravity pulls harder and harder on it.
3. When the satellite is slowed to the point where it cannot keep its orbit any more, the satellite falls.
4. The falling satellite gets very hot because of the friction of the air rubbing against it, and it will burn up unless it is protected from the heat.

G. Some satellites have stayed up as little as 3 months, whereas at least one satellite is expected to stay in orbit for about 200 years.

VI. Tracking the Satellite

A. Scientists follow the path, or track, of the satellite in two ways: by radar and by telescope.

B. Direction-finding antennas, set up at special receiving stations, and radar are used to fix the position of the satellite.

C. Satellites are seen best by telescope at early dawn or at twilight.
1. In the daytime the satellite is not bright enough to be seen against the bright, sunlit sky.
2. At night the satellite is often in the shadow of the earth.
3. At early dawn and twilight, the satellite is in sunshine while on earth we still have a dark sky, and thus we are able to see the satellite.

D. The satellite is filled with automatic instruments and recording devices.

E. These instruments get the electrical energy needed to operate them from any one of three sources, listed as follows:
1. **Chemical** batteries, which change chemical energy into electrical energy.
2. **Solar energy** batteries, which change solar energy into electrical energy.
3. **Nuclear energy** batteries, which use radioactive isotopes to change nuclear energy into electrical energy.

F. These instruments have already discovered, studied, and measured many things.
1. They have measured cosmic, X-ray, ultraviolet, and infrared radiation.
2. They have measured how strongly the earth is being bombarded by tiny meteors coming into the atmosphere from outer space.
3. They have studied the size and shape of the earth's magnetic field.
4. They have studied the earth's force of gravity at high altitudes.
5. They have discovered that the earth is not round like an orange, but is more pear-shaped or egg-shaped.
6. They have studied the height of the earth's atmosphere, and the atmosphere's temperature, pressure, and composition at high altitudes.
7. They have taken pictures of cloud patterns to be used in predicting the weather.
8. They have measured the magnetic field, temperature, and pressure near the moon, and have taken pictures of the side of the moon that we cannot see.
9. They have reflected radio, radar, and television signals back to earth.

VII. Kinds of Satellites

A. Satellites are now being sent into space so often that any printed list of each satellite and its accomplishment becomes dated very quickly.

B. Many persons describe the satellites by groups, or series, depending upon their design and what the satellites are supposed to do or find out.

C. **Scientific satellites** like the Explorer, Vanguard, Discoverer, and Monitor, all built and launched by the United States, carry a large variety of instruments that supply information about radiation, the earth's magnetic field, the earth's shape, temperatures in space, micrometeoroids, and other conditions in the upper parts of the atmosphere and in outer space.

1. The United States is also building and launching some scientific satellites in cooperation with other countries.
2. Examples of such satellites include the Ariel, which was built by the United States but filled with British instruments, and the Alouette, which was built by Canada and put into orbit by the United States.

D. **Weather satellites** like the Tiros series make weather observations, help scientists forecast weather more accurately, and contribute to a better understanding of what causes weather.

E. **Communications satellites** like the Score, Echo, Courier, Telstar, Relay, Syncom, and West Ford are being used to send and reflect radio signals, telecasts, telephone calls, teleprints, and telephotos to other parts of the world.

F. **Navigation satellites** like the Transit series help guide aircraft and ships at sea during any weather by broadcasting special radio signals.

G. A large number of **space probe satellites** are being used to explore the moon and the planets.

1. The Pioneer series investigates interplanetary space to learn more about solar radiation, interplanetary magnetic fields, and micrometeoroids.
2. The Ranger series gathers information about the moon to help pave the way for landing on the moon.
3. The Surveyor series is designed to land gently on the moon, send television pictures back to earth, find suitable landing sites, analyze the moon's crust, check the moon's surface for strength and stability, and measure the bombardment of the moon by meteorites.
4. The Mariner series is designed to fly near Venus and Mars and to send back information about these planets.

H. There are also special projects for launching man into space and then bringing him safely back to earth.

1. **Project Mercury** was organized to orbit a manned spacecraft, investigate man's reactions and abilities during space flight, and recover both man and spacecraft safely.
2. The purpose of **Project Gemini** is to determine man's performance and behavior during prolonged space flight, develop techniques that will enable two or more spacecraft to rendezvous and couple together while in orbit, carry out space investigations that need the presence of man in the spacecraft, and demonstrate both controlled re-entry into the atmosphere and controlled landing at a specific site.
3. The purpose of **Project Apollo** is to land men on the moon and then return them to earth.

VIII. Problems of Space Flight

A. *Getting enough thrust*

1. The earth pulls on all bodies with the force called gravity.
2. At the surface of the earth, the earth's pull of gravity on a body is the weight of that body.
3. A rocket is very heavy and needs a huge thrust merely to lift its own weight.

4. The rocket then needs an even greater thrust to travel many thousands of miles per hour so that it can rise high above or beyond the earth.
5. To send up bigger satellites, more powerful rockets must be used in order to give greater thrust.
6. Today most rockets are driven by a mixture of liquid fuel and liquid oxygen (LOX).
7. However, scientists are looking for fuels that will burn faster and hotter, thus producing more thrust.
8. Investigations are being made to see if nuclear energy or solar energy can be used to drive rockets.

B. *Escaping the earth's pull of gravity*

1. The farther away a body is from the earth, the smaller the earth's pull of gravity is.
2. The body now weighs less, even though it still has the same amount of material.
3. If the body travels high enough, it reaches a point where it is no longer affected by the pull of the earth's gravity.
4. At this point the body has no weight at all.
5. To reach this point the body must be launched from the earth's surface at a speed of 7 miles per second, or about 25,000 miles per hour.
6. This speed is called the **escape velocity** of the body.
7. Rockets launched at less than this speed are affected by the earth's pull of gravity, and eventually fall back to the earth's surface.
8. However, rockets launched at the speed of 25,000 miles per hour overcome the earth's pull of gravity and are free to travel out to other parts of the solar system.
9. Again, as satellites become bigger, more powerful rockets must be used to give a thrust great enough to reach escape velocity.

C. *Coming back to earth and landing*

1. The return to earth and landing is a problem.
2. To dive quickly into the atmosphere would produce so much heat, because of the friction of the air rubbing against the satellite, that the space ship would burn up.
3. One way of returning and landing safely is for the space ship to turn around and back down.
4. Rockets at the back of the space ship can be fired to produce a reverse thrust that makes it possible for the ship to return and land slowly and safely.
5. A second way of returning and landing safely is to have the returning ship go part way into the atmosphere, and then pull up again.
6. The ship can go through this procedure again and again, slowing down more and more as it goes deeper and deeper each time into the earth's atmosphere, until it is able to land safely without being burned up by friction.
7. A third way is to put a protective ceramic shield over the satellite's nose.
8. The shield absorbs the heat produced by air friction and burns up slowly while the satellite itself is not affected.

IX. Problems of the Astronaut During Space Travel

A. *The force of acceleration*

1. The astronaut must be able to endure the tremendous force acting upon him as the rocket speeds up, or accelerates, quickly.
2. This force is the same kind of force you feel when you go up quickly in an elevator.
3. You feel heavier, and it seems as if you are being pushed downward to the floor of the elevator car.
4. This force of acceleration really does make you heavier when you are speeding faster and faster, and going against gravity.

5. At the surface of the earth, the earth's pull of gravity on you is the weight of your body.
6. This pull, which is your weight, is called 1 g.
7. At a point during the first part of the flight, the astronaut feels a force of about 6 g's on him.
8. At this point, his weight is six times what it is on the ground.
9. At 3 g's a person cannot walk, and it is very hard to even move.
10. When seated, a person "blacks out" at 6 g's because his heart cannot pump blood to his brain against this great force of acceleration.
11. Tests show, however, that a person can endure this force without too much trouble if he is lying down on his back.
12. The astronaut must be able to endure the same force again when the rocket slows down, or decelerates, quickly.

B. *Weightlessness*
1. When the speeding up, or acceleration, stops and the rocket is in space, the astronaut and all the materials inside the rocket have no weight.
2. The earth's gravity has been left behind, and everything is weightless.
3. The astronaut loses his feeling of what is "up" and what is "down."
4. He must use suction cups on his shoes, or else he would float rather than walk across the space ship.
5. If the things inside the rocket were not nailed down, they would float about in the ship, too.

C. *Food and water*
1. Because of weightlessness, food and water can be a problem.
2. It is impossible to pour water from a bottle.
3. If the astronaut lifted food toward his mouth, the food would continue moving to the roof of the ship.
4. The astronaut must use food and water stored in tubes, like toothpaste tubes.
5. A large amount of dehydrated food can be stored in tubes or as compressed wafers.
6. The water problem can only be solved by recovering, purifying, and reusing all water over and over again.

D. *Air*
1. The astronaut needs a steady supply of oxygen, or he will die.
2. At the same time the carbon dioxide that he exhales must be removed.
3. One way of supplying oxygen is to use tanks of liquid oxygen, which can be mixed with helium gas also in tanks, to give the astronaut the right proportion of oxygen for breathing.
4. At the same time, chemicals can remove the carbon dioxide that the astronaut exhales.
5. Scientists are also experimenting with the use of tiny, green water plants, called algae.
6. These algae can produce large amounts of oxygen by photosynthesis and use the carbon dioxide that is given off by the astronauts.
7. The algae can also be used as food on very long trips.

E. *Heat and cold*
1. The chief problem in the airtight space ship is to keep cool, or to keep warm.
2. Most of the space ship's travel is in direct sunlight, and the sun's rays strike at least one side of the ship all the time.
3. As a result, the ship could become so hot inside that the astronaut would die.
4. One way to keep the ship cool is to have the outside of the ship smooth and silvery so that the sun's rays are reflected.
5. If the space ship travels far from the sun, where it is very cold, the outside of the ship can be painted black to absorb the sun's rays and warm the ship.
6. Another way of controlling the temperature inside the space ship is to paint one side of the ship silver, and the other side black.
7. The ship can then be turned to adjust the temperature whenever necessary.

F. *Radiation*
1. Cosmic rays can pass directly through the metal walls into the space ship.
2. Short exposure to these rays shows no harmful effects.
3. However, it may be that the astronaut will have to be protected from long exposure to cosmic rays.

G. *Meteors*
1. Meteors of all sizes are always traveling through space.
2. If a meteor should strike a space ship and puncture a hole in it, the air in the space ship would quickly rush out and the astronaut would die.
3. Double walls can protect the ship from small meteors.
4. Most meteors are very small, so it is not likely that the ship would be struck by a large meteor.

X. Space Stations

A. A large satellite spinning around the earth can be a space station.

B. The orbit of the satellite can be almost circular, and the satellite can be well outside the earth's atmosphere.

C. Because there is no air resistance at this altitude, the station can stay in orbit for hundreds of years.

D. Supplies can be sent to the station by rockets acting as freight cars.

E. A space station can have many valuable uses.
1. It can collect a vast amount of knowledge about the earth, its atmosphere, its weather, and its fields of gravity and magnetism.
2. It can be used to reflect and send back radio, radar, and television signals all over the earth.
3. During war it can watch for enemy troops and planes, and discover industrial targets.
4. It can be used to launch rockets easily into outer space because the rockets will not have to overcome the earth's pull of gravity to take off.

XI. Flight to the Moon

A. The first body in space that man will visit will be the moon.
1. It is the nearest body to us.
2. We have always been curious about our earth's only natural satellite.

B. It will be very difficult to build a rocket large and powerful enough to reach the moon.

C. Scientists must plan very carefully and skillfully to have the rocket hit the moon.

D. When planning the flight, they must consider the following factors.
1. The gravity of the earth, the moon, and the sun.
2. The rotation of the earth and the position of the moon in its orbit around the earth.
3. The tilt of the earth's axis and the tilt of the moon's orbit.

E. To land on the moon will be very hard and very dangerous.
1. For most of the trip there will be very little pull of gravity on the space ship.
2. But, about 24,000 miles from the moon, the moon's gravity will pull on the ship.
3. The ship will fall faster and faster toward the moon.
4. To stop from crashing into the moon, the ship will have to land tail first, using rockets at its tail to produce a reverse thrust that will act as a brake and help the ship land safely.

F. To take off from the moon will be easier than it is to take off from earth.
1. The moon's gravity is only one sixth that of the earth.
2. Also, the moon has no atmosphere.
3. Thus, much less thrust will be needed on the moon to put the ship up into space again.

LEARNING ACTIVITIES FOR "AIR, PLANES, AND SPACE TRAVEL"

AIR

1. *Air is present in the soil* · Put some loose soil in a water tumbler until the tumbler is half-full. Pour water in the tumbler until the tumbler is almost full. Bubbles of air will escape from the soil, showing the presence of air in soil.

2. *Air is present in water* · Fill a glass tumbler with cold water, and then set the tumbler aside for a few hours. Tiny bubbles of air will appear on the sides of the glass. Air is dissolved in the cold water. When the water becomes warmer, it cannot hold as much air so some of the dissolved air comes out of the water and forms bubbles on the side of the glass.

3. *Air is present in porous materials* · Drop a piece of building brick into a wide-mouthed glass jar that is three-quarters full of water. Bubbles of air will escape from the tiny pores in the brick.

4. *The percentage of oxygen in air* · Obtain two test tubes the same size. Insert a wad of steel wool all the way down to the bottom of one of the test tubes. Pour some water into each test tube, shake well, and then pour off the water. Put each test tube, mouth down, into a wide-mouthed jar or beaker of water and fasten each test tube with a clamp (Figure 12–1). Have the mouth of each test tube the same distance (about ½ inch) below the surface of the water. Let the test tubes stand this way for 24 hours.

Water will have risen up the test tube containing the steel wool. Nothing will have happened in the empty test tube, which serves as a control. Measure the length of the test tube above the surface of the water, and then measure how high the water rose in the test tube. Compare both lengths and you will find that the water has risen about one fifth, or 20 percent of the way up the test tube. Note the rusty appearance of the steel wool. The steel combined with the oxygen in the air inside the test tube to form iron oxide (rust). Since the water rose one fifth of the way up the tube to replace the oxygen, this rising means that about one fifth, or 20 percent, of the air in the tube was oxygen. The rest of the air is mostly nitrogen, with small amounts of inert gases, carbon dioxide, and water vapor.

5. *Carbon dioxide is present in the air* · Obtain some limewater from the drugstore. You can make your own limewater by obtaining some slaked lime from a hardware store. Place some slaked lime in a bottle, and then fill with water and shake well. Allow the mixture to settle overnight. The clear liquid above the settled material is limewater. Place some lime-

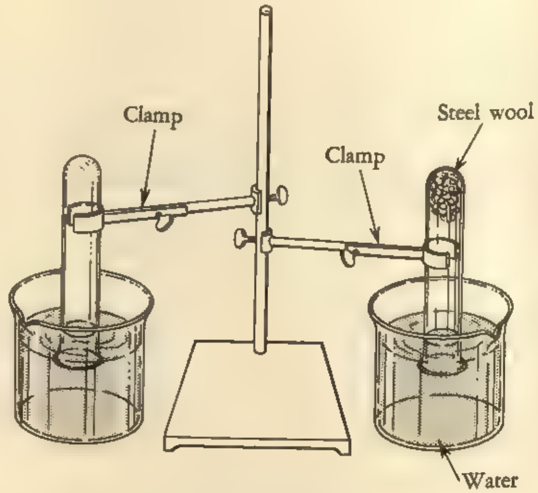


FIGURE 12–1.
ABOUT 20 PERCENT OF THE AIR IN THE TEST TUBE IS OXYGEN.

water in a small glass custard cup and leave the cup exposed to the air for a few hours. The limewater will become milky, showing the presence of carbon dioxide. The carbon dioxide combines with the limewater (which is calcium hydroxide) to form white, chalky calcium carbonate, which is suspended in the solution.

6. *The nitrogen cycle* · Draw a diagram on the chalkboard showing the nitrogen cycle (Figure 12–2). Trace the conversion of free nitrogen in the air into nitrogen materials that plants and animals can use, and then trace the conversion of the different nitrogen materials back into free nitrogen again.

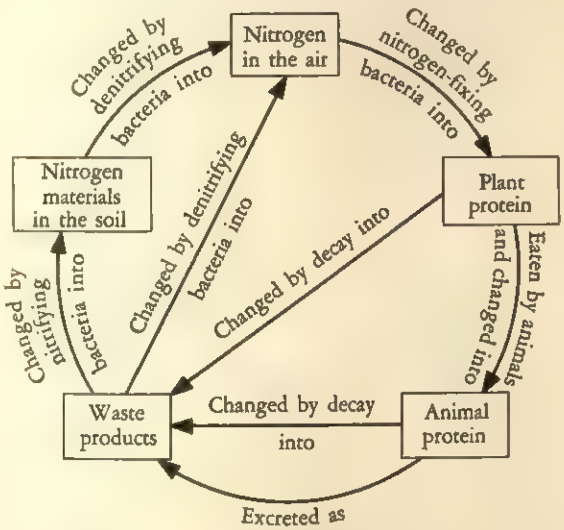


FIGURE 12–2.
DIAGRAM OF THE NITROGEN CYCLE.

7. *Water vapor is present in the air* · Repeat Learning Activity 8 of "Water in the Air," Chapter 11 (p. 385), showing the condensation of water vapor from the air.

8. *Dust is present in the air* · Cut out a piece of white paper so that it just fits the bottom of a deep cake tin. Place the paper in the tin, weight the paper down with one or two rocks, and then put the tin outside on the window sill. After a day or so, note the dust that has been deposited on the paper.

9. *Air pollution* · Have the children list the different ways that the air is being polluted in your community. Find out what measures your community has taken to control air pollution. Discuss the causes of smog, its effects, and methods of reducing or eliminating it. Have the children read about and report on radioactive fallout and the dangers that may result from an excess of this kind of air pollution.

10. *Layers of the atmosphere* · Make a chart or draw a diagram on the chalkboard of the four layers of the atmosphere. Include the height of each layer, and show the relative densities of the layers by using different shades of the same colored chalk or crayon.

Turn on the radio late at night and note how much easier it is to tune in distant radio stations than during the day. The sun affects the thickness of the ionosphere. The ionized layer of air that reflects radio broadcasts becomes wider after sunset and narrower when the sun rises.

11. *Air occupies space* · Crumple a dry paper napkin and stuff it firmly into a glass tumbler so that it will not fall out when the tumbler is held upside down. Now, while holding the tumbler upside down, push the tumbler straight down to the bottom of an aquarium or large glass jar that is filled with water (Figure 12–3). Note that the water does not fill the tumbler. The space in the tumbler is occupied by air. Tilt the tumbler slightly, and you will be able to see air as it escapes from the tumbler in the form of bubbles. Now lift the tumbler straight out of the water. Remove the paper napkin and note that it is still dry.

12. *Air has weight* · Place a pile of books at the edge of a table. Insert a flat stick about 12 inches long between the books and the table top. Tie one end of a string about 12 inches long to the flat stick, and tie the other end of the string around the middle of a yardstick,

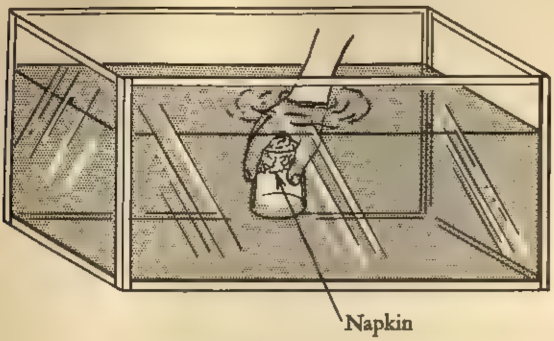


FIGURE 12–3.
BECAUSE AIR OCCUPIES SPACE, THE NAPKIN DOES NOT GET WET.

sliding the yardstick back and forth until it balances (Figure 12–4). Obtain two large, round balloons of the same size, and blow them up so that they are also the same size when inflated. Tie a string about 6 inches long around each balloon and hang each balloon near one end of the yardstick at the same distance from the ends. Slide the balloons back and forth along the yardstick until the yardstick balances evenly. Now puncture one of the balloons with a pin. The deflated balloon will not weigh as much as the balloon that still has air in it, and the yardstick will become unbalanced. (Note: When the balloon is punctured and bursts, a piece or two of the rubber may be blown off.

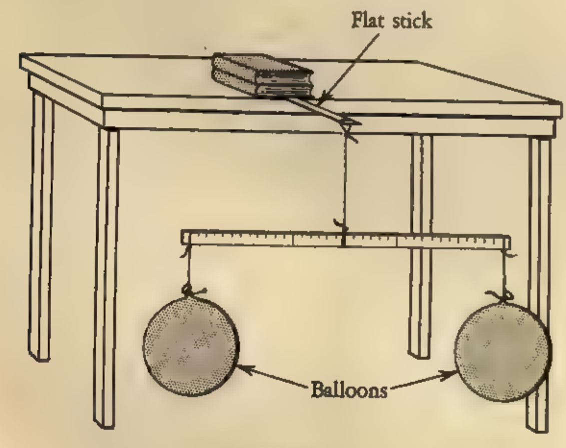


FIGURE 12–4.
AIR HAS WEIGHT.

Be sure to collect these pieces and drape them around the balloon. Otherwise the results will be inaccurate.)

If a sensitive balance is available, it is easy to show that air has weight. First weigh a football when deflated. Then fill the ball with air and weigh again.

13. *Air exerts pressure* · Fill a water tumbler to the top with water. Place a piece of cardboard on top of the tumbler and hold it firmly against the tumbler with the palm of one hand. Grasp the base of the tumbler with the other hand and quickly turn the tumbler upside down (Figure 12–5). Remove the palm of

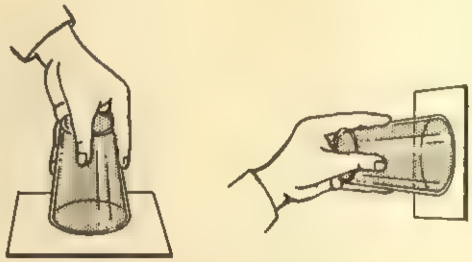


FIGURE 12–5.
AIR EXERTS PRESSURE IN ALL DIRECTIONS.

your hand carefully from below the cardboard, being careful not to jar the cardboard or the tumbler. The cardboard and the water will remain in place. Point out that the water stays in the tumbler because air is exerting a pressure on the cardboard. The pressure of the air against the cardboard is greater than the pressure of the water against the cardboard.

Turn the tumbler sideways and in many other positions. The water will still stay in the tumbler, showing that air exerts pressure in all directions. Point out that the perfect sphere of soap bubbles shows that the air in the bubbles is exerting pressure equally in all directions.

14. *Make a mercury barometer* · Obtain a thick-walled glass tube about 36 inches long and closed at one end. Place a small funnel in the open end of the tube and slowly add

mercury, to avoid the formation of air bubbles, until the tube is filled to the top. Place your finger over the open end of the tube, and invert the tube and place it in a beaker or tumbler that has about an inch of mercury in it (Figure 12–6). Do not remove your finger until the open end of the tube is below the surface of the mercury. When the finger is removed, the mercury in the tube will drop until the column of mercury in the tube is about 30 inches high. This column of mercury is supported by the pressure of the air on the surface of the mercury in the beaker. When the air pressure increases, the mercury is forced higher up the tube. When the air pressure decreases, the mercury in the tube will drop. If properly supported, and if there is a yardstick behind or beside it, the tube can be used as an accurate mercury barometer.

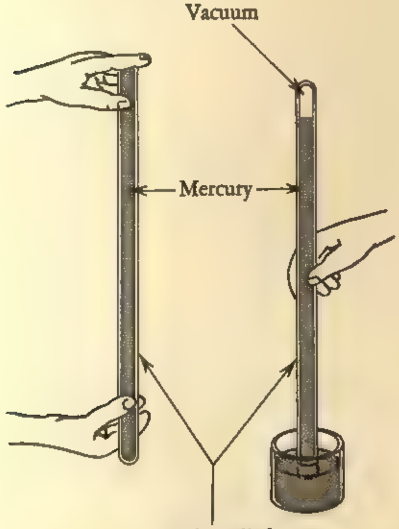


FIGURE 12–6.
A HOMEMADE MERCURY BAROMETER.

15. *Make an aneroid barometer* · Repeat Learning Activity 1 of "Predicting the Weather," Chapter 11 (p. 389), showing how to make a milk bottle aneroid barometer.

16. *Air pressure decreases as we go higher* · Take your homemade aneroid barometer up and down a steep hill. The higher you go, the lower the air pressure on the surface of the barometer, and the more the pointer will move down. The lower you go, the greater the air pressure, and the more the pointer will move up. The same effect can be produced by using an elevator in a tall building.

17. *Air exerts pressure against the sides of a container* · Blow up a balloon. The air exerts pressure against the sides of the balloon and inflates it. Push your finger against the balloon at different points. Note the pressure of the balloon, and of the air inside the balloon, against your finger.

18. *Adding or removing air changes the pressure inside a container* · Blow up a balloon and note the amount of pressure exerted when you poke your finger into the sides of the balloon. Blow more air into the balloon and note that there is an increase in pressure. Now deflate the balloon by letting out some air. Note the decrease in pressure against the sides of the balloon.

19. *Changing the size of the container will change the air pressure* · Get a very long, narrow balloon. Twist the balloon at the midway point. While keeping the balloon twisted, blow up one half of the balloon. Have one of the children poke the sides of the blown-up part of the balloon and note the pressure. Now untwist the balloon. The air inside will spread throughout the increased size in the balloon. Note the pressure of the air in the balloon. The air pressure decreased as the size of the container increases.

Blow a small amount of air into a balloon. Note the small amount of air pressure in the balloon. Now, while holding the neck with one hand, use your fingers of the other hand to push the air inside the balloon toward the end of the balloon. Note how, as the size of the container holding the air decreases, the air pressure increases.

20. *Heating and cooling will change the air pressure in a container* · Snap a balloon over the mouth of a Pyrex flask or bottle. Place the bottle on a hot plate and heat it for 1 minute (Figure 12–7). The air inside the bottle and balloon will expand when heated. This expanded air will exert pressure against the sides of the balloon and begin to inflate it. Now place the Pyrex flask into a pan of cold water containing ice cubes. The air inside the flask and balloon will contract when cooled and exert less pressure. As a result, the balloon will deflate, and it may even be drawn inside the flask because the decreased pressure inside the balloon is now so much less than the normal pressure of the air around the balloon.

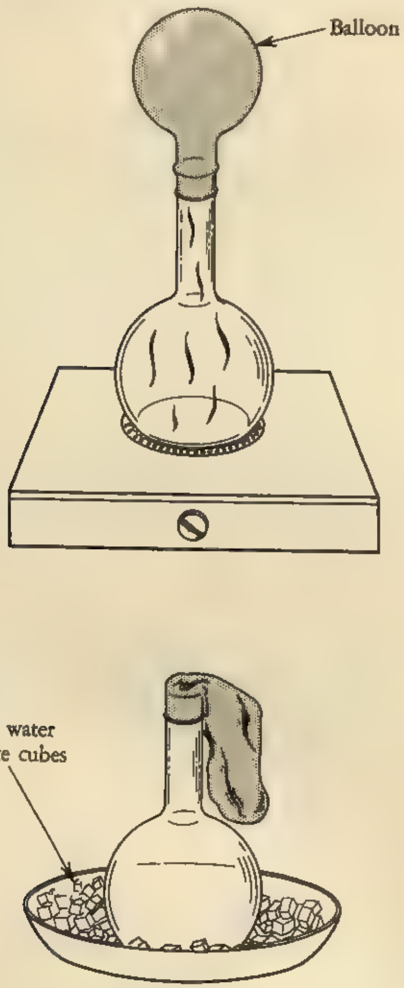


Figure 12–7.
AIR EXPANDS WHEN HEATED AND CONTRACTS WHEN COOLED.

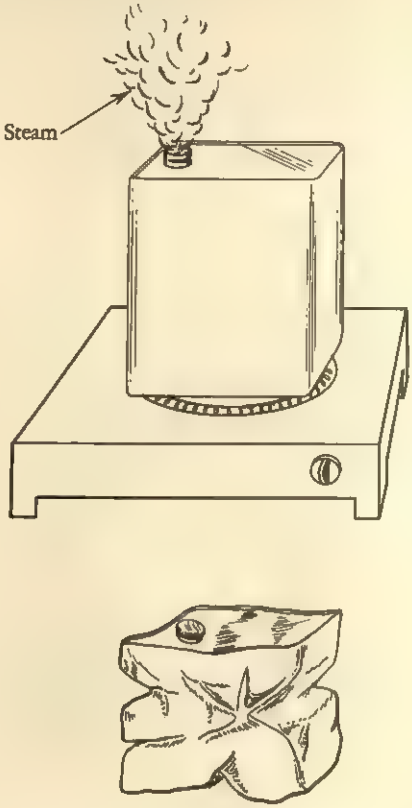


Figure 12–8.
WHEN THE AIR PRESSURE INSIDE THE CAN IS DECREASED, THE CAN COLLAPSES.

21. *Wind is moving air* · Have the children fan themselves with a piece of cardboard and feel the "wind" against their faces. An electric fan will produce an even stronger wind.

22. *Decreasing air pressure causes a can to collapse* · Obtain a large tin can that has a metal screw cap. A can that holds duplicator fluid will serve very well. Clean out the can and pour in a cup of water. Place the can on a hot plate (Figure 12–8) and heat the can, with the cap removed, until the water boils and steam comes out of the can for a minute or two. Remove the can from the hot plate,

using a pot holder or asbestos mitt, and quickly screw the cap tightly on the can. As the can cools, it collapses in spectacular fashion. By pouring cold water on the can at the sink, the collapse of the can will be hastened.

Point out that, as the water in the can boiled, the steam filled the can and drove out most of the air inside the can. When the can was stoppered and cooled, the water vapor inside the can cooled and condensed, leaving a partial vacuum and decreased air pressure inside the can. The air pressure outside the can, which is now greater, pushed inward on the sides of the can, causing the can to collapse.

23. *The effect of decreased air pressure on a soda straw* · Fill a drinking glass with milk or water and sip the liquid with the straw. Point out that sucking on the straw removes some of the air in the straw, producing a partial vacuum inside the straw. The air pressure on the surface of the milk in the tumbler is now greater than the air pressure inside the straw. The air pressure on the surface of the milk, which is now greater, pushes the milk up the straw (Figure 12–9).

24. *Decreased and increased air pressure operate a medicine dropper* · Place a medicine dropper in a tumbler of water and squeeze the rubber bulb. Note the bubbles of air leaving the medicine dropper, producing a partial vacuum inside the dropper. Now release the bulb, and water will be forced up the dropper. The air pressure on the surface of the water is now greater than the air pressure inside the dropper, and forces water up into the dropper. Remove the dropper from the tumbler and squeeze the bulb. The squeezing of the bulb compresses the air inside the dropper, and the increased pressure of the compressed air forces the water out of the dropper.

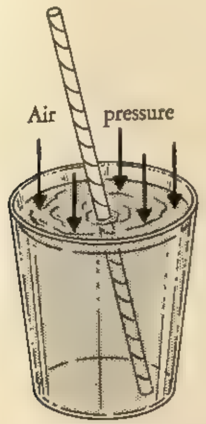


FIGURE 12–9.
USING DECREASED AIR PRESSURE TO SIP SODA FROM A STRAW.

25. *Effects of increased air pressure* · Place a paper bag on the table so that the mouth of the bag extends beyond the table's edge. Put a heavy book on top of at least half the paper bag. Now hold the mouth of the bag closely against your mouth without letting in any air and blow hard into the bag (Figure 12–10).

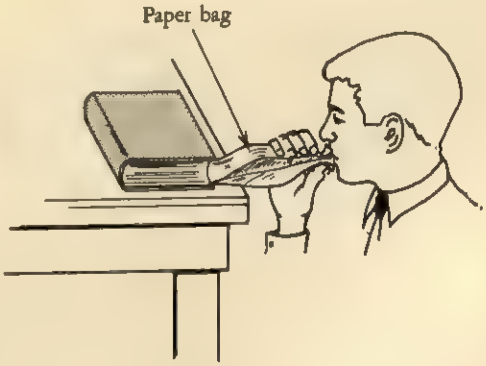


FIGURE 12–10.
USING INCREASED AIR PRESSURE TO LIFT A BOOK.

The increased air pressure will lift the book easily. Repeat the experiment, this time using two books.

Roll up a sheet of paper so that it forms a tube. Crumple a piece of paper into a round ball, whose size is such that it just fits inside the tube. Place the ball into one end of the tube and blow hard into this end (Figure 12–11). The ball will be shot out of the tube by the compressed air you created. Point out that air

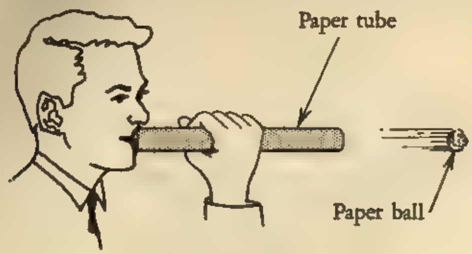


FIGURE 12–11.
HOW AN AIR GUN WORKS.

guns and air hammers are common examples of this method of using compressed air.

Press the pin in the valve of a bicycle or automobile tire and feel the force of the compressed air that is released. Use an air pump to inflate a tire, football, or basketball.

PLANES AND ROCKETS

1. *Bernoulli's principle* · Place one end of a sheet of paper between the pages of a book so the paper hangs downward. Now hold the top of the book level with your lips and blow over the top of the paper (Figure 12–12). The sheet of paper will rise because the fast-moving stream of air across the top of the paper causes the air pressure on the top surface of the paper to be less than the air pressure underneath the paper.

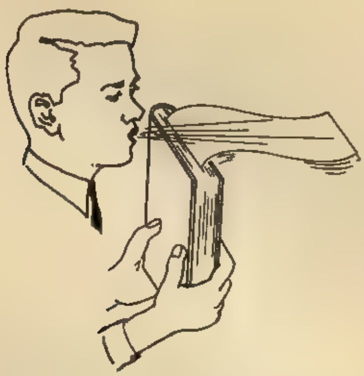


FIGURE 12–12.
USING BERNOULLI'S PRINCIPLE TO MAKE THE PAPER RISE.

2. *Effect of a curved wing on lift* · Obtain a 5 × 8 inch index card and cut a strip lengthwise that is not more than 2 inches wide. Bend and staple one end of the strip over about 1 inch of the other (Figure 12–13). The upper surface

FIGURE 12–13.
A CURVED SURFACE PRODUCES LIFT.

will now be curved like the wing of a plane, but the bottom surface will be comparatively straight. Slip a round pencil or a knitting needle through the loop and blow across the upper, curved surface of the cardboard wing. A lift will be produced on the wing. Because the air across the upper surface moves faster than the air across the lower surface, the air pressure on top of the wing is less than the air pressure underneath, and the wing is lifted up.

3. *Effect of wingspread on lift* · Obtain two model planes, one with a larger wingspread than the other. Point out that the greater the wingspread, the more air passes over and under the wings, and the greater the lift will be.

4. *Angle of attack* · Demonstrate with a model plane that the wing is tilted at a slant or angle so that the air can strike the underside of the wing as well. Repeat Learning Activity 2 above, but this time blow against the bottom surface of the wing. The air striking the underside of the wing pushes up on the wing and adds to the lift.

5. *The propeller produces a thrust* · Examine the propeller of a model plane and note the curve of the blades. The blades are curved in

such a way that, as the propeller spins, they push the air backward, producing an opposite forward thrust. Place a series of round pencils underneath a flat board. Then put a small electric fan (with a long extension cord) on top of the board (Figure 12–14). Turn on the fan. The fan blows air in one direction and, as a result, moves in the opposite direction.

6. *Newton's law of action and reaction* · Obtain a plastic bottle, preferably a flat one, and a cork to fit the mouth of the bottle. Fill the bottle about one-third full of vinegar. Place a teaspoon of baking soda on a small piece of cleansing tissue, wrap the tissue into a roll, and twist the ends. Drop the roll into the bottle, give the bottle one good shake to break up the roll, and push the cork into the bottle firmly, but not too firmly. Immediately place the bottle on three or four round pencils, in the position shown in Figure 12–15. In a very short time the cork will blow out of the bottle, and the bottle itself will move in the direction opposite to that of the cork.

The baking soda reacts with the vinegar to form carbon dioxide gas, which pushes in all directions. When the force is strong enough, the gas blows the cork out of the bottle. As the gas shoots out of the bottle in one direction,

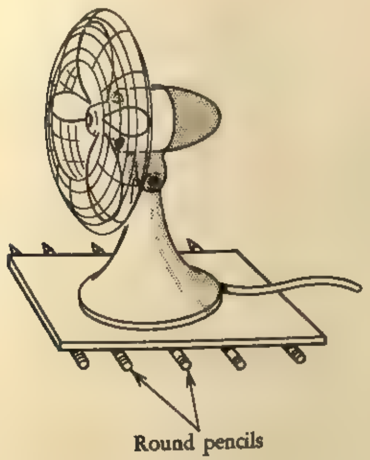


FIGURE 12–14.
THE CURVED BLADES OF THE FAN PRODUCE A THRUST.

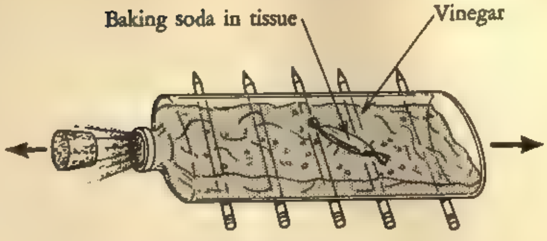


FIGURE 12–15.
ACTION AND REACTION IN A CORKED BOTTLE.

we get an equal but opposite force that moves the bottle in the opposite direction. The bottle moves a shorter distance than the cork because it is heavier than the cork.

The same effect of action and reaction can be seen when a boy on roller skates or seated in a wagon throws an object like a stone. The boy will move in a direction opposite to the stone that is thrown.

7. *Jet engines* · Draw or make models of such jet engines as the ramjet, turbojet, and turboprop engines, and explain their operation. Show how the jet engines get their thrust from hot gases that, escaping with a great backward force, produce an equal but opposite forward force or thrust.

8. *A jet-propelled balloon* · Inflate a long, narrow balloon and tie a string in a bow around the neck of the balloon. Attach the balloon to a soda straw, using cellophane tape, as shown in Figure 12–16. Run a long wire through the soda straw and attach both ends of

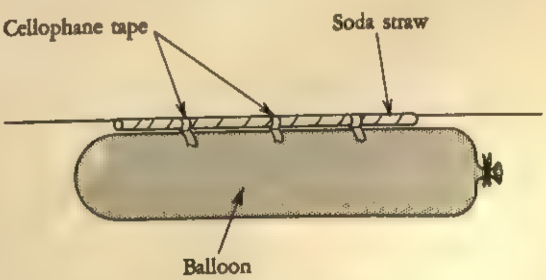


FIGURE 12–16.
MAKING A BALLOON ACT LIKE A JET PLANE.

the wire to opposite parts of the room, keeping the wire horizontal. Now untie the string so that the air can escape. The balloon will be "jet-propelled" across the room.

When the balloon is filled with air and the string is tied around its neck, the balloon does not move because the air pressure inside the balloon is equal in all directions. When the string is untied and air begins to escape from the balloon, the air pressure inside the balloon becomes unequal. The air pressure is now greater on the surface opposite the neck of the balloon because the air pressure on the neck decreases as the air escapes. Therefore the balloon moves in a direction opposite to that of the escaping air.

9. *Drag* · Have a child hold a large cardboard in front of him and run into the wind. The resistance of the air against the cardboard will produce a drag and slow down the child's forward motion.

10. *Streamlining* · Bend one end of a 5 × 8 inch index card all the way over to the other end and staple the two ends together. The cardboard will now have a tear-drop shape. Set the index card on edge and place a burning candle in front of the pointed end (Figure 12–17). Blow against the rounded end of the card and the flame will be extinguished. When the air hits the streamlined card, the air stream divides in two, each traveling smoothly around the card and meeting at the end to blow out the flame.

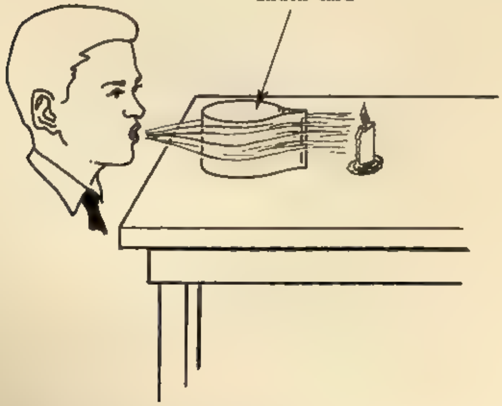


FIGURE 12–17.
STREAMLINING HELPS BLOW OUT THE CANDLE FLAME.

11. *Parts of a plane* · Have a child bring in a model plane and point out the parts of the plane and their functions. If possible, conduct a field trip to a nearby airport. This trip will give the children an opportunity to observe and study firsthand the different kinds of planes, their parts and functions, the plane instruments and their functions, the way the runways are arranged, the safety devices on the landing field, the control tower, directions for takeoff and landing, the refueling of planes, the loading and unloading of cargo and passengers, and the different kinds of weather instruments.

12. *How a plane takes off and climbs* · Obtain a model of a plane that has movable elevators, rudder, and ailerons. If a plane with such movable parts is not available, make the parts out of cardboard and attach them firmly with cellophane tape to the tail and wings of the model plane. The rudder part should be able to move to the right and left, and the elevators and ailerons should be able to move up and down. Use cellophane tape to attach four lengths of strong cotton thread to the nose, each wing, and tail of the plane, as shown in Figure 12–18. Adjust the lengths of the threads so that, by holding all four ends in one hand, the plane will be suspended horizontally in the air.

Now push both elevators up, hold the plane in front of an electric fan, and turn on the fan. The air stream will strike the elevators and force the tail down, which swings the nose of the plane up, making it possible for the plane to take off or climb.

13. *How a plane dives and lands* · Repeat Learning Activity 12 above, but this time make the elevators tilt down. The air stream will strike the elevators and force the tail up, which

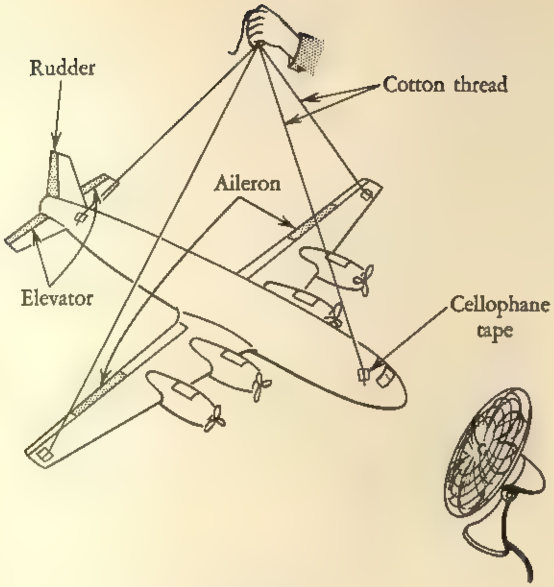


FIGURE 12–18.
SHOWING HOW THE PARTS OF A PLANE WORK.

swings the nose of the plane down, making it possible for the plane to dive or land.

14. *How a plane turns to the right and to the left* · Repeat Learning Activity 12 above, but this time make the right aileron go up, the left aileron go down, and swing the rudder to the left. The air stream strikes the ailerons and makes the right wing fall and the left wing rise. This action makes the plane roll on its side and turn, or bank, to the right. The air stream also strikes the rudder and makes the nose of the plane turn to the right. Point out that the function of the rudder is to help prevent the plane from yawing, or skidding sideways, when the plane makes its turn.

Repeat the experiment, but this time make the right aileron go down, the left aileron go up, and swing the rudder to the right. The plane will now turn, or bank, to the left.

15. *The sound barrier* · Blow up a paper bag and strike it suddenly, causing the bag to burst with a loud noise. Point out that a shock wave was produced that is similar to that of the sound barrier.

16. *The heat barrier* · Show how heat can cause a metal to melt, by holding a piece of lead (using forceps) in the flame of a Bunsen burner or alcohol lamp. Point out that the tremendous heat produced by the friction of the air moving across the metal parts of the plane may cause the parts to melt.

17. *The helicopter* · Obtain a model of a helicopter. Point out that the spinning propeller pushes the air downward, producing a reaction or thrust that forces the helicopter upward. Make your own helicopter by gluing a wooden or plastic propeller firmly to the top of a small, round stick or dowel (Figure 12–19). Twirl the stick very rapidly between your

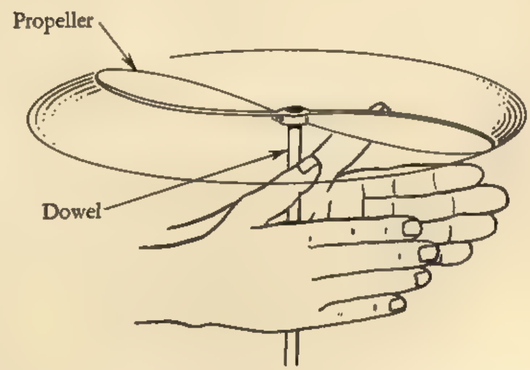


FIGURE 12–19.
HOW A HELICOPTER PROPELLER WORKS.

hands and then let go. The stick will rise into the air.

18. *Rockets* · Draw or make a model of a rocket and explain how it works. Compare the difference between rockets and jets in the kind of fuel used, source of oxygen, and region of travel.

SPACE TRAVEL

1. *Early space travel* · Have the children read about and report upon early space exploration with rockets.

2. *Multistage rockets* · Draw or make a model of a multistage rocket and explain the function of each stage in getting the rocket into space and orbit.

3. *Why rockets are launched toward the east* · Use cellophane tape to attach a small cardboard cutout of a rocket to a globe of the earth. Spin the globe from west to east, in the direction of the earth's rotation, and show how the earth's speed of rotation gives the rocket an extra push of about 1000 miles per hour, which helps the rocket reach the speed it needs to go into orbit.

4. *Why a satellite stays in orbit* · Repeat Learning Activities 4, 5, and 6 of "The Solar System," Chapter 9 (p. 276). At the same time, explain how a satellite can overcome the earth's gravity and go off into space.

5. *The path of a satellite* · Repeat Learning Activity 2 of "The Solar System," Chapter 9 (p. 275). Draw orbits that vary from almost perfect circles to long, narrow ovals. Locate the apogee and perigee of each orbit.

6. *Tracking the satellite* · Have the children read about and report on the use of the telescope and radar to track satellites. Have them also report on the instruments inside the satellites and their function.

7. *Kinds of satellites* · Have the children write to the Office of Educational Programs, National Aeronautics and Space Administration (NASA), 400 Maryland Avenue, S.W., Washington 25, D.C. They will receive *NASA Facts*, which is a bulletin issued periodically. In the bulletins there is detailed information on the different kinds of satellites, their function, what they have studied and measured, and what they have learned. Have the children look for articles on satellites published in weekly magazines and in newspapers.

8. *Problems of space flight* · Have the children read about and report on such problems of space flight as getting enough thrust, escaping the earth's pull of gravity, landing on and leaving the moon or another planet, and returning to and landing on the earth.

9. *Problems of the astronauts* · Have the children read about and report on the problems of survival the astronauts will encounter in space travel. These problems will include the tremendous force of acceleration and deceleration, weightlessness, food and water, sufficient oxygen, disposal of carbon dioxide and of body wastes, heat and cold, bombardment by cosmic rays and other deadly radiations, bombardment by meteors, and mental problems caused by prolonged isolation.

Repeat Learning Activity 2 of "Winds," Chapter 11 (p. 382) to show how making one side of the space ship black will keep the ship warm whereas making the other side of the space ship white or silvery will keep the ship cool.

BIBLIOGRAPHY FOR "AIR, PLANES, AND SPACE TRAVEL"

ADLER, IRVING, *Man-Made Moons: The Earth Satellites and What They Will Tell Us.* New York: Day, 1957. 128 pp.

BEELAND, LEE, and ROBERT WELLS. *Space Satellite.* Englewood Cliffs, N.J.: Prentice-Hall, 1957. 79 pp.

BEELER, NELSON F., and FRANKLYN M. BRANLEY. *Experiments with Airplane Instruments.* New York: Crowell, 1953. 115 pp.
BENDICK, JEANNE. *The First Book of Airplanes.* New York: Watts, 1958. 63 pp.
———. *The First Book of Space Travel.* New York: Watts, 1953. 69 pp.
BERGAUST, ERIK. *Satellites and Space Probes.* New York: Putnam, 1959. 48 pp.
BRANLEY, FRANKLYN M. *A Book of Moon Rockets for You.* New York: Crowell, 1959. Unpaged.
———. *A Book of Satellites for You.* New York: Crowell, 1959. 48 pp.
———. *Experiments in the Principles of Space Travel.* New York: Crowell, 1955. 119 pp.
COGGINS, JACK, and FLETCHER PRATT. *By Space Ship to the Moon.* New York: Random, 1952. 58 pp.
COOKE, DAVID C. *How Airplanes Are Made.* New York: Dodd, 1956. 72 pp.
COOMBS, CHARLES. *Skyrocketing into the Unknown.* New York: Morrow, 1954. 256 pp.
DEL REY, LESTER. *Rockets Through Space.* New York: Holt, Rinehart & Winston, 1960. 118 pp.
DIETZ, DAVID. *All about Satellites and Space Ships.* New York: Random, 1962. 137 pp.
FISHER, JAMES. *The Wonderful World of the Air.* New York: Doubleday, 1958. 70 pp.
FORRESTER, FRANK H. *Exploring the Air Ocean.* New York: Putnam, 1960. 70 pp.
FREEMAN, MAE. *You Will Go to the Moon.* New York: Random, 1959. 54 pp.
FRISKEY, MARGARET. *The True Book of Air Around Us.* Chicago: Childrens, 1953. 47 pp.
GOTTLIEB, WILLIAM P. *Aircraft and How They Work.* New York: Doubleday, 1960. 56 pp.
———. *Jets and Rockets and How They Work.* New York: Doubleday, 1959. 56 pp.
GURNEY, GENE. *Americans into Orbit: The Story of Project Mercury.* New York: Random, 1962. 140 pp.
HOLSAERT, EUNICE. *A Book to Begin on Outer Space.* New York: Holt, Rinehart & Winston, 1959. 48 pp.
HYDE, MARGARET O. *Flight Today and Tomorrow.* New York: McGraw, 1962. 139 pp.
KINNEY, WILLIAM. *Medical Science and Space Travel.* New York: Watts, 1959. 150 pp.
KNIGHT, CLAYTON. *The How and Why Book of Rockets and Missiles.* New York: Grosset, 1960. 48 pp.
KNIGHT, DAVID C. *The First Book of Air.* New York: Watts, 1961. 68 pp.
LEWELLEN, JOHN. *Birds and Planes: How They Fly.* New York: Crowell, 1953. 134 pp.
———. *The Earth Satellite.* New York: Knopf, 1957. 59 pp.
———. *Helicopters: How They Work.* New York: Crowell, 1954. 136 pp.
———. *Tommy Learns to Fly.* New York: Crowell, 1956. 48 pp.
LEY, WILLY. *The Conquest of Space.* New York: Viking, 1958. 160 pp.
MUNCH, THEODORE W. *What Is a Rocket?* Chicago: Benefic, 1959. 48 pp.

NEWELL, HOMER E., JR. *Guide to Rockets, Missiles, and Satellites.* New York: McGraw, 1958. 54 pp.

PARKER, BERTHA M. *The Air About Us.* New York: Harper, 1958. 36 pp.

———. *Gravity.* New York: Harper, 1958. 36 pp.

———. *Our Ocean of Air.* New York: Harper, 1956. 36 pp.

———. *Rockets and Missiles.* New York: Harper, 1961. 36 pp.

———. *Satellites and Space Travel.* New York: Harper, 1961. 36 pp.

PAUST, GILBERT HARRY. *How a Jet Flies.* New York: Sterling, 1962. 72 pp.

PILTZ, ALBERT. *What Is Air?* Chicago: Benefic, 1960. 48 pp.

PINE, TILLIE S., and JOSEPH LEVINE. *Air All Around.* New York: McGraw, 1960. 48 pp.

PODENDORF, ILLA. *The True Book of Space.* Chicago: Childrens, 1959. 47 pp.

POOLE, LYNN. *Ballooning in the Space Age.* New York: McGraw, 1958. 160 pp.

RUCHLIS, HY. *Orbit.* New York: Harper, 1958. 147 pp.

RUSH, HANNIFORD. *The Wonderful New Book of Project Apollo: Man to the Moon.* Chicago: Rand McNally, 1962. 96 pp.

SHIPPEN, KATHERINE B. *A Bridle for Pegasus.* New York: Viking, 1951. 192 pp.

VICTOR, EDWARD. *Planes and Rockets.* Chicago: Follett, 1965. 32 pp.

VON BRAUN, WERNHER. *First Men to the Moon.* New York: Holt, Rinehart & Winston, 1960. 96 pp.

LIVING THINGS

CHAPTER

13 Plants

SECTION ONE: Plants with Seeds

CLASSIFICATION OF PLANTS

I. Classifying Living Things

A. All living things are grouped into two main divisions, called **kingdoms**: the **plant kingdom** and the **animal kingdom**.

B. These two divisions, the plant and animal kingdoms, are subdivided into major groups called **phyla**.
1. Phyla are large groups of plants and animals.
2. All the members of a phylum have certain broad similarities in structure and in other characteristics.

C. The phyla are subdivided into smaller groups called **classes**, the classes into orders, the orders into **families**, the families into **genera**, the genera into **species**, and the species into **varieties**.
1. A class is a finer subdivision of a phylum.
2. An order is one of several groups within a class.
3. A family is a group within an order.
4. A genus is a smaller group within a family.
5. A species is a group of very closely related plants or animals.
6. A variety is an individual of a species that varies slightly from other individuals in the same species, but not enough to be considered a separate species.

D. The further the phyla are subdivided into smaller groups, the greater the similarity there is among the members that make up each group.

E. When classifying plants or animals, scientists give each phylum and its subgroups a scientific name made up of Latin words.
1. This scientific naming makes the classification of each plant or animal quite definite so that there can be no duplication.
2. The scientific name also describes the plant or animal well enough so that it can be readily identified.
3. The scientific name also helps show relationships between different plants or animals.
4. Because Latin is a common language, the scientific names can be understood and used by people of all countries.

II. The Plant Kingdom

A. Usually the plant kingdom is divided into four major phyla: the **Thallophytes**, the **Bryophytes**, the **Pteridophytes**, and the **Spermatophytes**.

B. The plant kingdom is also commonly di-

vided into two broad groups: plants that produce seeds, and plants that do not produce seeds.

C. Of the four plant phyla, the Thallophytes, Bryophytes, and Pteridophytes do not produce seeds, but the Spermatophytes do produce seeds.

D. Plants are the only living things that can make their own food, but not all plants can.

E. To make its own food, a plant needs a green material, called **chlorophyll.**

III. The Thallophytes

A. The Thallophytes are very simple plants, with no roots, stems, and leaves.

B. Scientists divide the Thallophytes into two smaller groups: **algae** and **fungi.**

C. Algae have chlorophyll and can make their own food.
   1. They usually grow in water, and are colored.
   2. The blue-green, green, brown, and red algae belong to this subphylum.

D. Fungi do not have chlorophyll so they cannot make their own food.
   1. They get their food either from living or dead plants or animals.
   2. Some are colorless, and others have a variety of colors.
   3. Bacteria, yeasts, molds, and mushrooms belong to this subphylum.

IV. The Bryophytes

A. The Bryophytes are also very simple plants, but they have a more complicated structure than the Thallophytes.
   1. They have simple leaves, but no true roots and stems.
   2. However, they do have rootlike and stemlike parts.

B. They have chlorophyll, are colored green, and can make their own food.

C. They live mostly on land.

D. Mosses and liverworts belong to this phylum.

V. The Pteridophytes

A. The Pteridophytes have true roots, stems, and leaves, but they do not have flowers, fruits, and seeds.

B. They range in size from small mosslike plants to plants the size of a small tree.

C. They have chlorophyll, are colored green, and can make their own food.

D. Ferns and club mosses belong to this phylum.

VI. The Spermatophytes

A. The Spermatophytes include all the plants that produce seeds.

B. All trees, shrubs, crop plants and vegetables, garden and wild flowers, weeds, and grasses are seed plants.

C. Seed plants grow in soil and in fresh water.

D. The smallest seed plants are tiny, floating duckweeds, which are about ¼ inch across.

E. The largest seed plants are the giant sequoias (or redwood trees) of California, which can grow more than 300 feet tall.

F. Scientists divide seed plants (Spermatophytes) into two groups: **angiosperms** and **gymnosperms.**
   1. The seeds of angiosperms are enclosed in a protective coat, called a **fruit.**
   2. The seeds of gymnosperms are unprotected.

VII. Gymnosperms

A. Gymnosperms are older seed plants than the angiosperms.

B. They are also called **conifers** because they produce woody cones.
   1. The cone is the "fruit" of the conifers, and is made up of scales.
   2. The unprotected seed lies on top of the ripe cone.

C. Examples of conifers include pine, spruce, fir, cedar, bald cypress, redwood, hemlock, yew, and larch trees.

D. Conifer leaves are either in the form of needles or flat scales.
   1. Conifers keep their leaves for two to five years, except the bald cypress and larch trees, which lose their needles each autumn.
   2. Because their leaves stay green all winter, conifers are also called evergreen trees.
   3. When new leaves grow, they appear in the spring.
E. The trunk of the conifers does not divide, but grows tall and straight, and most of the branches are usually found nearer the top of the trunk.
F. Conifers give off a sticky substance, called **resin**, and this resin is characteristic of conifers only.
G. The wood of conifers is usually soft, and is widely used for lumber and making paper.
H. Conifers are also used to stop the force of the wind around farms, and as decorative trees in parks and yards.

VIII. Angiosperms

A. Angiosperms are seed plants, producing flowers that form fruits with seeds inside them.
B. This group includes all garden and wild flowers, weeds, plants that produce crops and vegetables, grasses, cereal grains, and all trees and shrubs that lose their leaves in the autumn.
C. They have broad, flat leaves, which they lose each year.
   1. This is the reason why they are called **deciduous** plants.
   2. The word deciduous comes from the Latin word "to fall."
D. Angiosperm trees have a trunk that may divide into two, and their branches begin rather low on the trunk.
E. The angiosperms, or flowering plants, are divided into two large groups: the **monocotyledons** or **monocots**, and the **dicotyledons** or **dicots**.
   1. A **cotyledon** is a special kind of leaf found in the seed.
   2. The cotyledon has food stored in it, which feeds and nourishes the tiny plant inside the seed when the seed sprouts and grows into a new plant.
   3. Monocotyledon plants produce seeds that have just one of these seed leaves, and dicotyledon plants produce seeds with two seed leaves in them.
   4. Most of the monocotyledons are small, and include such plants as the lily, tulip, iris, onion, the cereal grains, and the coconut and date palms.
   5. The dicotyledons include most of our flowers, vegetables, shrubs, and flowering trees.

IX. Herbaceous and Woody Plants

A. Scientists also divide plants into two broad groups: **herbaceous** and **woody** plants.
B. A herbaceous plant is any plant with a soft stem, which may or may not be green.
   1. This soft stem lasts for only one growing season, and then dies to the ground.
   2. Flowers, common weeds, garden vegetables, and the cereal grains are all herbaceous plants.
C. A woody plant has a hard stem, and is usually colored brown.
   1. This hard stem does not die, but continues to grow year after year.
   2. The stem grows both longer and wider each year.
   3. Examples of woody plants include trees, shrubs, and such vines as the wild grape and poison ivy.

X. Parts of a Flowering Seed Plant

A. Every part of a flowering seed plant has special functions.
B. The roots, stems, and leaves of flowering seed plants carry out all the processes the plants need to live, except that of producing seeds.
C. The root has the following functions.

1. It holds the plant firmly in the ground.
2. It takes in water and minerals from the soil and conducts them to the stem for delivery to the leaves.
3. Many roots store food for the plant.

D. The stem has the following functions.

1. It produces the leaves and holds them up to the sunlight.
2. It conducts water and minerals from the roots to the leaves.
3. It also carries the food, which the leaves make, down to the roots.
4. Some stems store food for the plant.

E. The leaf, which is one of the most important parts of the plant, has the following functions.

1. It makes the food that the plant needs to live.
2. It lets gases in the air, such as carbon dioxide and oxygen, enter and leave the plant.
3. It allows water in the plant to escape into the air.

F. The flower is the special part of the plant that produces seeds from which new plants can grow.

1. Flowers produce fruits with seeds inside them.
2. The fruit is the protective covering for the seed.
3. The seed is the part of the plant that can grow into a new plant.

ROOTS

I. Definition and Kinds of Roots

A. The roots are the part of the plant that grows downward into the ground.

1. When a seed first begins to grow, a root grows rapidly and pushes its way into the soil.
2. This root is called the **primary root.**
3. After a while, **secondary roots** branch out from the primary root, first near the top of the primary root, and then farther down.
4. The roots keep branching and rebranching until a complete root system is formed.

B. There are two main kinds of root systems: the **taproot system** and the **diffuse root system.**

C. In the taproot system, the primary root grows until it is the largest root in the root system.

1. This large root is called the **taproot.**
2. Much smaller secondary roots grow from this large taproot.
3. Dandelions and carrots have taproots.

D. In the diffuse root system, the primary root lives only for a short time.

1. The secondary roots then continue to grow as a cluster at the base of the stem.
2. These secondary roots are all thin, have the same size, and are called **fibrous roots.**
3. Beans, corn, and grasses have fibrous roots.

E. Some taproots and fibrous roots store food for the plant and become large.

1. These large roots are called **fleshy roots.**
2. Beets, carrots, and radishes are examples of fleshy taproots.
3. Dahlias and sweet potatoes are examples of fleshy fibrous roots.

F. In some plants, roots grow from the stems or leaves of the plant.

1. These kinds of roots are called **adventitious roots.**
2. The tomato, cucumber, and squash plants form adventitious roots when their stems touch the ground.
3. The leaves of the begonia, sedum, and sansevieria plants form adventitious roots when placed in the soil.

G. Some plants send out roots from their stems just above the ground.

1. These roots are a special kind of adventi-

tious root, called **prop roots** or **brace roots.**

2. They grow into the ground and help hold the plant upright.
3. The corn plant is an example of a plant with prop or brace roots.

H. Climbing plants, such as English ivy, poison ivy, and tropical orchids, send out roots from their stems.

1. These roots are also a special kind of adventitious root, called **aerial roots.**
2. The aerial roots grow in the air, clinging to a wall or tree and holding the stem firmly in place.

II. The Structure of the Root

A. A short distance behind the tip of each root are many tiny, fuzzy **root hairs.**

1. These root hairs take in, or absorb, water and dissolved minerals from the soil.
2. As the root moves downward into the soil, new root hairs form near the tip, and the older root hairs wither and die.

B. At the tip of the root is the **root cap,** which protects the delicate end of the root.

C. The length of the root varies, according to the needs of the plant and conditions of the environment.

1. The taproot of the mesquite plant has been known to grow 40 feet down into the desert to reach a water supply.
2. The diffuse roots of a cactus plant cover large areas just below the surface of the ground to absorb quickly the water from infrequent rains.
3. The eggplant and squash roots grow downward about 7 feet and spread sideways from 2 to 20 feet.

III. The Functions of Roots

A. The roots absorb, or take in, water and dissolved minerals from the soil, and send them to the stem and up into the leaves of the plant.

1. The water and dissolved minerals are absorbed by the root hairs.
2. The root hairs give off an acid that helps dissolve the minerals in the soil.

B. The roots also help hold the plant firmly in place.

C. Some roots, such as the beet, carrot, sweet potato, and dahlia, help store food for the plant.

D. Some roots, such as the sweet potato and dahlia, can produce new plants.

E. Roots adapt to the needs of the plant and conditions of the environment.

IV. Use of Roots

A. Some roots, such as the carrot, turnip, parsnip, radish, beet, and sweet potato, are used for food.

B. Some roots, such as the horseradish, are used for seasoning foods.

C. Some roots, such as sassafras, ginger, licorice, and mandrake, are used for medicines.

D. Some roots, such as licorice and ginger, are used in making candy.

E. The roots of the madder and yellowwood trees are used to make dyes.

STEMS

I. Definition and Kinds of Stems

A. The stem of a plant is the part of the plant between the roots and the leaves.

B. Stems may be found above the ground, below the ground, or both above and below the ground.

C. There are two basic kinds of stems: **monocotyledon stems** and **dicotyledon stems.**

D. A plant with a monocotyledon stem grows from a seed with only one **cotyledon** or seed leaf in it.
   1. Monocotyledon plants, or monocots, can usually be recognized by their narrow, smooth-edged, parallel-veined leaves.
   2. The iris, orchids, lilies, corn, grasses, and palms are examples of monocotyledon plants.

E. A plant with a dicotyledon stem grows from a seed with two cotyledons or seed leaves in it.
   1. Dicotyledon plants, or dicots, can usually be recognized by their broad, irregularly shaped, spread-veined leaves.
   2. The tomato, geranium, buttercup, bean, rose, and all woody trees and shrubs are examples of dicotyledon plants.

F. The trunk of a tree is actually the stem of the plant.
   1. The trunk of the palm tree is an example of a giant monocotyledon stem.
   2. The trunk of the oak or the elm tree is an example of a giant dicotyledon stem.

G. Scientists also classify stems as **herbaceous** stems and **woody stems.**

H. Herbaceous stems are usually soft and green, and have no woody tissue in them.
   1. They grow longer, but not thicker, and live only one season.
   2. The stems of tomatoes, beans, peas, corn, grasses, and most annual flowers are herbaceous stems.

I. Woody stems are brown and stiff, and have woody tissue in them.
   1. They grow both longer and thicker, form branches, and live season after season.
   2. The stems of trees and most shrubs are woody stems.

J. A stem that grows above the ground is called an **aerial stem.**
   1. Aerial stems vary in length, ranging from less than 1 inch to more than 100 feet tall.
   2. There are four main groups of aerial stems: **shortened stems, creeping stems, climbing stems,** and **erect stems.**

K. Shortened stems are very small stems.
   1. Sometimes they are so short that they seem to be missing from the plant.
   2. The dandelion, primrose, and carrot all have shortened stems.
   3. Their very short, flat, circular stems can be seen growing just above the roots.
   4. Plants with shortened stems need open places to grow, where they can get lots of light.

L. Creeping stems are long and slender, and stay close to the ground.
   1. These stems do not have woody tissues and are weak, so they grow along the surface of the ground.
   2. The stems are also called **runners** or **stolons.**
   3. The strawberry plant and creeping bent grass have creeping stems.
   4. Plants with creeping stems also need open places to grow, where they can get lots of light.

M. Climbing stems are thin and very long.
   1. They do not have woody tissues and are weak, so they grow into the air by wrapping themselves around and around a tall object.
   2. The ivy, morning glory, and sweet potato all have climbing stems.

N. Erect stems stand above the ground by themselves.
   1. They may be either a few inches tall or many hundred feet high.
   2. They may be either herbaceous or woody.
   3. Trees, shrubs, and most garden flowers have erect stems.

O. A stem that grows below the ground is called an **underground stem.**
   1. Because they are located underground, most persons do not usually think of them as stems.
   2. There are four main groups of underground stems: **rhizomes, tubers, bulbs,** and **corms.**

P. Rhizomes are long, underground stems that grow horizontally close to the surface of the ground.
   1. Some rhizomes are thick and fleshy, and

filled with food; examples are the rhizomes of the iris, the lily of the valley, and the trillium.

2. Other rhizomes are thin, such as those of quack grass and other grasses.

Q. Tubers are the enlarged tips of rhizomes, with food stored in them.

1. The white potato is an example of a tuber.
2. The "eyes" of the potato are really buds from which new growth begins.

R. A bulb is made up of a stem shortened to the size of a disk, surrounded by thick, fleshy, scalelike leaves.

1. The leaves have food stored in them.
2. The hyacinth, tulip, daffodil, and onion are examples of bulbs.

S. A corm is different from a bulb only in that most of it is stem.

1. This stem is surrounded by thin, scale-like leaves.
2. The crocus and gladiolus are examples of corms.

II. External Structure of a Woody (Dicotyledon) Stem

A. The bare, winter twig of a tree is an excellent example of a woody stem.

B. The twig has **buds** on it.

1. Each bud is a place on the stem where a new stem, leaves, and flowers can grow.
2. In cold climates the delicate buds are protected by overlapping **bud scales.**

C. Most twigs have a **terminal bud** at their tip.

D. Along the sides of the twig are **lateral buds,** from which branches may grow.

E. Along the twig there are also oval, circular, or shield-shaped **leaf scars,** which mark the spots where leaf stalks were attached during previous seasons.

F. The **node** is a point on the leaf scar where leaves or branches were produced by the stem.

G. Also along the twig there are rings circling the twig, called **bud-scale scars.**

1. These bud-scale scars show the exact locations of the terminal buds during previous seasons.
2. By starting at the present terminal bud and counting the number of bud-scale scars along the twig, one can find out the exact age of the twig.

H. Some twigs have thorns, which help in identifying the plant.

1. Some thorns are short and broad, others are long and pointed, and still others are branched.
2. The thorns help protect the twigs.

I. Stems grow in length by forming new growth at their tips, or, in some cases, at their nodes or sides.

III. Internal Structure of a Woody (Dicotyledon) Plant

A. There are three distinct regions inside the branch or trunk of a woody tree: the **bark,** the **wood,** and the **pith** in the center.

B. The bark is the outer covering of the stem.

1. The bark has two parts: the outer and the inner part.
2. The outer bark protects the stem from injury, from disease, and from losing water.
3. The inner part of the bark conducts the food made by the leaves downward to the roots.

C. Sometimes bark-chewing animals, such as beavers, porcupines, deer, and horses, remove a circular section of the bark all the way around a tree.

1. The removal of bark in this way is called **girdling.**
2. Girdling will kill a tree because food cannot get down to the roots.

D. The wood of the stem is made up of hollow tubes, which conduct water and dissolved minerals upward from the roots to the leaves.

1. In an old stem there are often two kinds of wood: the **sapwood** and the **hardwood.**
2. The sapwood is live wood, and conducts

water and dissolved minerals up from the roots to the leaves.

3. The sapwood contains the liquid sap of the tree.
4. The hardwood is dead wood, and its only use is to support the tree.
5. The hardwood is the part of the tree that man uses to make furniture and other articles.

E. The pith is in the center of the stem.

1. In an old, woody stem the pith is hardly noticeable, but in a young stem, because there is still little wood in it, the pith seems to be quite large and serves as a place to store food.
2. However, the size of the pith is the same in both cases because the pith never grows larger.
3. Regardless of how large a tree becomes, the pith never grows larger than the size it was during the first year of the stem's growth.

F. Between the bark and the wood of a stem there is a fourth region, called the **cambium**, which is made up of a very thin layer of delicate tissue.

1. Each spring and summer the cambium forms new wood and new inner bark for the stem.
2. As a result, each year a new layer of wood is added to the stem.
3. This new layer of wood forms a circle or ring, called an **annual ring**, inside the stem.
4. This formation of layers makes it possible to estimate the age of a tree by counting the number of annual rings in a cross section of a tree trunk or stem.

IV. The Structure of a Herbaceous Stem

A. A monocotyledon herbaceous stem has a hard, outer covering called a **rind**, and a dicotyledon herbaceous stem has a thin skin called an **epidermis**.

B. The monocotyledon herbaceous stem does not have a cambium, but the dicotyledon herbaceous stem has a cambium.

C. Because both stems live only one year, the stems are usually long and thin.

D. The bundles of hollow tubes inside a monocotyledon herbaceous stem are scattered at random inside the stem; however, in a dicotyledon herbaceous stem, the bundles of hollow tubes are arranged regularly in a circle inside the stem.

V. The Functions of Stems

A. Stems conduct water and dissolved minerals upward from the roots to the leaves.

B. Stems also conduct food from the leaves downward to the roots.

C. The stem produces and displays the leaves so that they receive the sunlight they need.

D. Most stems support the plant and hold it erect.

E. Green herbaceous stems can make food for the plant.

F. Some stems, like the potato, store food for the plant.

G. Some aerial stems, such as the coleus, philodendron, strawberry, and black raspberry, can grow new plants.

H. Most underground stems can grow new stems.

VI. Uses of Stems

A. The potato, asparagus, and celery are used for food.

B. The sap of the maple tree and the juice of the sugar cane produce sugar.

C. Cinnamon bark is used to make spice for flavoring.

D. Rubber is made from the sap of the rubber tree.

E. The stem of the flax plant is used to make linen.

F. The cinchona bark produces quinine, which is used to treat malaria.

G. The bark of the cherry tree is used for cough syrups.

H. Camphor comes from the laurel tree, and witch hazel comes from the witch hazel shrub.

I. Ropes and all kinds of string are made from the fibers of hemp and other plants.
J. The bark of many trees is used to make dyes.
K. Turpentine from the pine tree is used in paint and varnish.
L. The wood of trees is used for making lumber, furniture, paper, telegraph and telephone poles, piles for piers, parts of machines, and wooden boxes, baskets, and barrels. Some people use wood for heating their houses and cooking their food.

LEAVES

I. Parts of a Leaf

A. A leaf has two main parts: the **blade** and the **petiole.**
  1. The blade is the flat, thin, green part of the leaf.
  2. The petiole is the stalk of the leaf, and is attached to the stem of the plant at a node.
  3. Some leaves do not have a petiole, but are fastened directly to the plant stem.

B. The blade of the leaf has **veins** in it.
  1. The veins are tiny, hollow tubes that carry water, dissolved minerals, and food between the leaf and the stem.
  2. The veins also help strengthen the leaf and make it firm.
  3. Leaves that do not have a petiole (stalk) are fastened directly to the stem by the veins.

C. There are three main patterns in which the veins of a leaf are arranged: **palmate, pinnate,** and **parallel** patterns.

D. In the palmate vein pattern, there are a few large veins that start at the tip of the petiole and spread out very much like the outstretched fingers of your hand.
  1. Smaller veins, called **veinlets,** then branch out from these large veins to all parts of the leaf.
  2. The geranium, maple, and sycamore leaves have palmate vein patterns.

E. In the pinnate vein pattern, there is just one large vein, called a **midrib.**
  1. Smaller veins (veinlets) branch out on each side of the midrib, giving the same effect or appearance as the arrangement in a feather.
  2. The elm and willow leaves have pinnate vein patterns.

F. In the parallel vein pattern, there are many large veins running parallel, or side by side, from the bottom of the leaf to its tip.
  1. Parallel vein patterns are found in the leaves of the lily, iris, and the grasses.
  2. Parallel veins are found mostly in the leaves of monocotyledon plants, whose seeds have only one seed leaf (cotyledon).

II. Kinds and Shapes of Leaves

A. The size and shape of a leaf is tied up with the arrangement of the veins in the leaf.
  1. Leaves with parallel veins are long and thin.
  2. Leaves with pinnate veins are shorter and wider than those with parallel veins.
  3. Leaves with palmate veins are usually broad.

B. Leaves have different kinds of edges.
  1. Some edges are smooth, like the leaves of the willow, redbud, and magnolia.
  2. Some edges are toothed, like the leaves of the elm.
  3. Some leaves have lobes, or fingerlike projections, like the leaves of the maple.

C. If the blade of a leaf is all in one piece, it is called a **simple leaf.**
  1. It is still a simple leaf, even if the leaf is lobed or greatly indented.

2. Maple, oak, elm, and apple leaves are simple leaves.

D. If the blade of the leaf is divided into three or more separate parts, called **leaflets**, the leaf is called a **compound leaf.**

1. Clover, horse chestnut, locust, ash, and strawberry leaves are compound leaves.
2. When the leaflets spread out or radiate from a single common point, as in the horse chestnut and the clover, the leaf is called a **palmately compound leaf.**
3. When the leaflets are arranged on each side of the midrib, or opposite each other, as in the ash and the pea, the leaf is called a **pinnately compound leaf.**

E. The leaves of the evergreen trees are different from other leaves.

1. In evergreens, such as the pine and the spruce, the leaves are very thin and like needles.
2. In evergreens, such as the cedar, the leaves are like scales.

III. The Leaf and Photosynthesis

A. The main function of the leaf is to make food for the plant.

B. Only green plants are able to make their own food.

1. Green plants have a green material in the leaf, called **chlorophyll.**
2. Chlorophyll gives the leaf its green color.
3. Chlorophyll also makes it possible for the leaf to make food for the plant.

C. The leaf uses two materials to make food: water and **carbon dioxide.**

D. The water comes from the ground, together with dissolved minerals, passing into the roots, up the stem, and into the leaf.

E. Carbon dioxide is a gas in the air.

1. There are many tiny openings, called **stomata,** in the leaf, especially in the underside of the leaf.
2. The carbon dioxide gas in the air passes through these openings (stomata) into the leaf.

F. By using the energy of sunlight, the chlorophyll in the leaf makes it possible for the carbon dioxide and water to combine and form a sugar, called **glucose,** and **oxygen** gas.

G. This food-making process in the plant is called **photosynthesis.**

1. "Photo" means "light."
2. "Synthesis" means "putting together."

H. The leaf changes the sugar (glucose) to starch, either immediately or soon afterward.

I. The leaf also changes some of the sugar into fats and proteins.

J. The food made by the leaf then is carried to the stem and the roots for use or for storage.

K. Oxygen gas is a waste product of photosynthesis, and is given off into the air through the stomata of the leaf.

L. Green stems that have chlorophyll in them can also make food for the plant.

IV. The Leaf and Transpiration

A. Although the plant needs water to make food and for other uses, the plant usually takes in more water than it needs.

B. The excess water passes through the stomata into air as water vapor.

1. This evaporation of water from the plant is called **transpiration.**
2. The amount of water that a plant gives off by transpiration is very great.
3. A sunflower gives off 1 quart of water a day.
4. An average-sized tree can give off as much as 50 quarts of water a day during the summer.

C. Tiny cells, called **guard cells,** control the amount of water that passes out of the leaf.

1. Each one of the stomata is surrounded by two of these guard cells.
2. Usually the guard cells keep the stomata wide open, allowing water to leave the plant freely.
3. But, when the plant does not have enough water and is wilting, the guard cells make the stomata smaller, which

slows down the evaporation of water from the leaf.

D. Although transpiration takes place mostly in the leaves, other parts of the plant can allow transpiration to take place as well.

V. OTHER FUNCTIONS OF THE LEAF

A. The leaf helps the plant digest the food and change the food into the energy it needs to live and grow.

B. The leaf helps the plant remove waste materials.

C. Some leaves, such as the sedum, sansevieria, and African violet, can grow new plants.

VI. SOME LEAVES CHANGE COLOR IN THE FALL

A. During the late spring and summer the leaves keep making chlorophyll and stay green.

B. In the fall, when it becomes cold enough, the leaves stop making chlorophyll, and the green color in the leaves disappears.

C. The hidden yellow and orange colors in some of the leaves now begin to appear.

D. The cool weather and the increase in the amount of moisture in the air also produce red colors in other leaves.

E. When the weather becomes still colder, the leaves die and turn brown, and then fall to the ground.

VII. USES OF LEAVES

A. Some leaves are used for food.

1. The leaves of the lettuce, cabbage, spinach, endive, parsley, and kale are eaten by man.
2. Tea leaves are used to make a beverage.
3. The leaves of spearmint, peppermint, sage, and thyme are used for spices and flavoring.

B. Tobacco leaves are used for smoking.

C. Leaves, such as palm and grass, are used to cover the roofs of the homes of natives in the tropics.

FLOWERS

I. DEFINITION AND PARTS OF A FLOWER

A. The flower is a special part of a plant that produces new plants of the same kind.

1. The flower lives for a short time only, and then parts of the flower become a fruit.
2. The fruit has seeds in it, and the seeds produce the new plants.

B. The large, flattened part of the stalk that holds the flower is called the **receptacle.**

C. Most flowers have four parts: **sepals, petals, stamens,** and **pistil.**

D. Sepals are the thin, green, leaflike parts on the outside of the flower.

1. They cover and protect the flower bud.
2. When the bud opens, the sepals separate and fold back.
3. They then support and protect the open flower.
4. All together the sepals are called the **calyx** of the flower.

E. Inside the sepals (calyx) are the petals of the flower.

1. The petals are usually larger than the sepals, and are brightly colored.
2. All together the petals are called the **corolla** of the flower.
3. At the base of the petals there are usually little pockets or cups of a sweet liquid, called **nectar,** which is attractive to bees and other insects.

F. In some flowers, like the tulip and the lily, both the sepals and the petals are the same color.

G. Inside the petals, and usually grouped in

a ring around the center of the flower, are the stamens.

1. The stamens are the male part of the flower.
2. There are two parts to a stamen: the filament and the **anther.**
3. The filament is the thin stalk or stem of the stamen.
4. The anther is on top of the filament, and is usually knobby or boxlike.
5. The anther produces a yellow or reddish powder called **pollen.**

H. In the center of the flower, usually surrounded by the stamens, is the pistil.

1. The pistil is the female part of the flower.
2. There are three parts to a pistil: the stigma, the **style,** and the **ovary.**
3. The stigma is the sticky top of the pistil.
4. The style is the thin stalk or stem of the pistil.
5. The ovary is the large or swollen bottom of the pistil.
6. Inside the ovary are one or more **ovules,** which will later become seeds.

I. A flower, such as the rose or the lily, that has all four parts (sepals, petals, stamens, and pistil) is called a **complete flower.**

J. A flower, such as the willow or the oat, that has one or more of its parts missing is called an **incomplete flower.**

K. If a flower, such as the oat or wild ginger, has both stamens and pistil, even if its sepals and petals are missing, it is called a **perfect flower.**

L. If a flower, such as the pussy willow or cottonwood, has either the stamens or the pistil missing, it is called an **imperfect flower.**

M. Some flowers are not really a single flower but are a whole cluster of individual flowers.

1. Such flowers are called **composite flowers.**
2. Examples of composite flowers include the zinnia, aster, daisy, chrysanthemum, marigold, and dandelion.

N. The flowers of monocotyledon plants are different from the flowers of dicotyledon plants.

1. Monocotyledon plants have seeds with only one seed leaf (cotyledon), and dicotyledon plants have seeds with two seed leaves.
2. Monocotyledon flowers, such as the tulip and the lily, have their flower parts in threes or in multiples of three, such as six or nine.
3. The tulip has three sepals and three petals (both the same color), six stamens, and a pistil with three parts to its ovary.
4. Dicotyledon flowers, such as the rose, buttercup, and columbine, usually have their flower parts in fours or fives, or in multiples of fours or fives.

II. Pollination and Fertilization

A. For seeds to be formed, the pollen from the anther of a stamen must be carried to the sticky stigma of the pistil.

1. This transfer of pollen is called **pollination.**
2. When the pollen is carried from the anther to the stigma in the same flower, or to the stigma of another flower on the same plant, it is called **self-pollination.**
3. When the pollen is carried from the anther of one flower on one plant to the stigma of a flower on another plant, it is called **cross-pollination.**

B. Pollination can take place in many ways.

1. The pollen may just fall from the anther to the stigma.
2. The wind may blow pollen from flower to flower.
3. Water may carry pollen from flower to flower of plants that live in the water.
4. As insects, like the bee, crawl into flowers to look for nectar, they pick up pollen on their hairy bodies and carry the pollen from flower to flower.
5. Hummingbirds, looking for nectar, also carry pollen on their beaks and long tongues from flower to flower.
6. Man occasionally carries on pollination,

called **artificial pollination**, when he wants to develop new kinds of flowers, fruits, vegetables, corn, and wheat.

C. The process of self-pollination does not occur often.
   1. In some flowers the stamens are too short for the pollen to fall on the pistil.
   2. In some flowers the stamens lose their pollen before the pistil is grown enough and ready to receive the pollen.
   3. Some flowers, called **imperfect flowers**, do not have stamens or a pistil.

D. When a grain of pollen from the right kind of flower falls on the stigma, it starts to form a **pollen tube**, which grows down the stigma and the style into the ovary.
   1. In the ovary, the pollen grain enters an ovule through a tiny opening, called a **micropyle**, and joins with the egg that is in the ovule.
   2. The joining of the pollen grain with the egg in an ovule is called **fertilization**.
   3. For fertilization to take place, a flower's stigma must receive pollen that comes from the same kind of flower.
   4. When fertilization does take place, the ovule develops into a seed.
   5. Seeds are formed only if fertilization takes place, and, if an ovule is not fertilized, a seed will not be formed in that ovule.

III. The Selective Breeding of Flowers

A. Very often man tries to produce certain kinds of flowers.

B. He produces these new flowers by controlling the pollination of flowers.
   1. This controlled pollination is called **artificial pollination**.
   2. In artificial pollination, pollen from one flower is transferred carefully by hand to the stigma of another flower of the same kind.
   3. Usually, the flower with the stigma has had its stamens removed before the pollen was ripe to make sure that no other pollen could be transferred to that stigma.
   4. After the flower has been artificially pollinated, it must be protected from visits by insects, which may have pollen on their hairy bodies.

C. This control of pollination by man is also called **selective breeding**.

D. In selective breeding, man tries to combine different qualities of two varieties of the same flower into one new variety of the same flower.
   1. For example, man may try to combine a large flower with little fragrance with a small, but fragrant, flower to produce a large, fragrant flower.
   2. Many new varieties of flowers, especially roses, have been produced by selective breeding.
   3. A new variety of flower is called a **hybrid**.

IV. Uses of Flowers

A. Because of their beauty, flowers are used everywhere for decorative purposes.

B. The buds of the cauliflower are used for food.

C. Cloves are the dried flower buds of the myrtle tree, which grows in the tropics.
   1. The buds are used as a seasoning or spice.
   2. The buds also produce an oil that is used in medicines.

D. Saffron, a yellow dye, comes from the stigmas of the saffron crocus.

E. Flowers are used in making perfumes.

FRUITS

I. Definition and Function of Fruits

A. After the ovule in the ovary of a flower has been fertilized, seeds form and the ovary becomes large.
B. A fruit is the ripened ovary of the flower, with or without other parts of the flower.
C. The fruit is the part of the plant that contains the seeds that are formed.
D. To many persons the word "fruit" means only tree fruits, such as the apple, pear, peach, orange, grape, and banana.
E. To a scientist, however, the word "fruit" means the ripened ovary from any flowering plant.
  1. As a result, all our "vegetables" are fruits.
  2. All our cereal grains, such as corn, wheat, and oats, are fruits.
  3. All our nuts are fruits.
  4. All our garden and wild flowers, shrubs, and flowering trees produce fruits.
F. A fruit has two main functions.
  1. One function is to protect the seeds inside it.
  2. The other function is to help scatter the seeds.
G. Fruits are classified into two main groups: **fleshy fruits** and **dry fruits.**
  1. Fleshy fruits are soft and fleshy when ripe.
  2. Dry fruits are dry when ripe.

II. Fleshy Fruits

A. Fleshy fruits are classified into three main groups: **pomes, drupes,** and **berries.**
B. In the pome, the fleshy part is formed by the sepals (calyx) and the large, flattened end of the flower stalk, which is called the **receptacle.**
  1. The papery core of the pome is really the ovary, and has the seeds in it.
  2. The apple, pear, and quince are examples of such pomes.
  3. The strawberry is a pome in which many tiny, hard fruits (ripened ovaries) are embedded in one fleshy receptacle (flower stalk).
  4. The strawberry was formed this way because its flower had many pistils inside it.
  5. Pomes usually have many seeds in them.
C. In the drupe, the ovary wall ripens into two layers.
  1. The outer layer becomes soft and fleshy.
  2. The inner layer becomes very hard.
  3. There are usually one or two seeds in this hard, inner layer.
  4. The plum, peach, apricot, cherry, and olive are examples of drupes.
  5. The almond comes from a drupe; however, here we throw away the fleshy, outer part and eat the seed of the hard, inner part.
  6. The raspberry and blackberry are really collections of many tiny drupes clustered on one receptacle.
  7. The raspberry and blackberry were formed this way because their flowers had many pistils inside them.
D. In the berry, the whole ovary becomes fleshy.
  1. Some berries, such as the tomato, grape, and gooseberry, have rather soft, thin skins.
  2. Some berries, such as the canteloupe, watermelon, and cucumber, have hard skins.
  3. Some berries, such as the orange, lemon, and grapefruit, have leathery skins.
  4. Berries usually have many seeds in them.
E. The pineapple is a fleshy fruit that is really made up of many fruits joined together.
  1. This kind of fruit is called a **multiple fruit.**
  2. A multiple fruit forms from many flowers that are clustered together.
  3. The mulberry is another example of a multiple fruit.

III. Dry Fruits

A. Dry fruits are classified into two main groups: **dehiscent** and **indehiscent** fruits.
B. Dehiscent fruits are further divided into **pod** fruits and **capsule** fruits.
1. Pod fruits, such as the bean, pea, and milkweed, split open along definite seams when ripe.
2. Capsule fruits, such as the poppy, iris, and lily, crack open when they are ripe.
3. Both pod and capsule fruits have many seeds in them.
C. Indehiscent fruits do not split open along definite seams and do not open when they are ripe.
1. Indehiscent fruits usually have just one or two seeds inside them.
2. Some indehiscent fruits, such as the acorn, hazel nut, and chestnut, have a hard ovary wall covering the seed.
3. Some indehiscent fruits, such as the corn, wheat, and oat, have a thin ovary wall fastened to the seed.
4. In some indehiscent fruits, such as the sunflower, buttercup, and dandelion, the seed is not fastened to the ovary wall, but is separated from the ovary wall.
5. In some indehiscent fruits, such as the elm, maple, and ash, the seed is also separated from the wall, but there are winglike growths attached to the ovary wall.

IV. Some Fruits Do Not Have Seeds

A. Some fruits develop from the flower without forming seeds.
B. The banana is a seedless fruit.
1. Banana trees do not ordinarily produce seeds.
2. Instead, new sprouts grow from the roots each season, and their flowers produce more bananas without being fertilized.
3. What looks like seeds in the banana are really unfertilized ovules.
C. Seedless oranges, grapefruits, and grapes are produced by joining (or **grafting**) parts of seedless trees onto the roots and stems of ordinary trees that produce these fruits with seeds in them.

V. Selective Breeding

A. Man is always trying to improve the kinds of fruit we eat.
B. For example, he may try to make fruit larger, give the fruit more flavor, make the skin smooth instead of hairy, get more seeds in the fruit, eliminate seeds from a fruit, make fruit mature earlier, and make fruit sturdier and more resistant to disease.
C. Man improves the fruit by **selective breeding.**
1. In selective breeding man controls the pollination of the flower that produces the fruit.
2. To control this pollination he carefully transfers by hand the pollen from one flower to the stigma of another flower of another kind.
3. In this way he tries to combine different qualities of two varieties of the same fruit into one new variety of the same fruit.
4. To make sure that no other pollen will touch that stigma, usually the stamens of the flower with the stigma are removed before their pollen is ripe.
5. Also, after the flower has been artificially pollinated, it is protected from visits by insects, which might have pollen on their hairy bodies.
6. This new variety of fruit is called a **hybrid.**
D. Sometimes man creates new fruits.
1. He creates new fruits by transferring the pollen from a flower that produces one kind of fruit to the stigma of a flower that produces another kind of fruit.
2. The tangelo is a new fruit that is produced by crossing a tangerine with a grapefruit.
3. The plumcot is a new fruit produced by crossing a plum with an apricot.

SEEDS

I. Definition and Parts of a Seed

A. A seed is the part of a plant that grows into a new plant of the same kind.
   1. The seed is a ripened ovule that has been fertilized by a grain of pollen.
   2. The ovule is in the ovary of a flower's pistil.

B. All seeds have three parts: a seed coat, stored food, and a tiny young plant, called the **embryo.**

C. The seed coat is the covering of the seed.
   1. The seed coat protects the seed.
   2. Most seeds have two seed coats, but some seeds have only one seed coat.
   3. The outer coat is usually thick and tough, and the inner coat is much thinner.

D. The stored food helps the young plant grow until it can make its own food by photosynthesis.
   1. Some seeds store their food in thick seed leaves, called **cotyledons.**
   2. These seed leaves (cotyledons) are not true leaves, but part of the seed.
   3. Monocotyledon plants, such as the corn plant, have only one seed leaf (cotyledon) in their seeds.
   4. Dicotyledon plants, such as the bean plant, have two seed leaves (cotyledons) in their seeds.

E. The embryo is a tiny, young plant inside the seed.
   1. The embryo has tiny roots, a stem, and leaves that will become the new plant.
   2. When the embryo begins to grow, it lives on the stored food inside the seed until its leaves are able to make their own food for the plant.

II. Conditions Necessary for Seeds to Grow

A. Seeds need water to grow.
   1. The water makes the seed swell.
   2. It also softens the seed coat.

B. Seeds need the right temperature to grow.
   1. Most seeds grow best when the temperature ranges between 60 and 80 degrees Fahrenheit.
   2. Some seeds grow better in higher temperatures.

C. Seeds need air to grow, and this is the reason why the soil in the garden must be loose and the seeds must be planted close to the surface of the soil.

D. Seeds need room to grow, and they grow best when they are scattered away from the plant that produced them.

E. Seeds do not need sunlight when they first begin to grow.
   1. At first they live off the stored food in each seed.
   2. When the new plant grows leaves, it needs sunlight to make its own food.

III. How Seeds Grow

A. When a seed begins to grow, we say that it sprouts or **germinates.**

B. First, the seed takes in, or absorbs, water.
   1. The water makes the seed swell and softens the seed coat.
   2. This softening of the seed coat allows the tiny plant (embryo) inside the seed to grow out through the seed coat.

C. In most seeds, the roots are the first part to grow.

D. Then the stem grows up into the air.

E. The tiny leaves unfold, forming the first true leaves of the plant.

F. While the roots, stem, and true leaves are forming, the young plant lives off the stored food inside the seed.
   1. As long as the young plant depends upon the stored food to live, it is called a **seedling.**
   2. In the bean seed, which is a dicotyledon plant, the two cotyledons (seed leaves) grow with the stem above the ground.
   3. In the corn seed, which is a monocotyle-

don plant, the one cotyledon (seed leaf) stays below the ground.

4. When the young plant is able to make its own food and no longer needs any of the stored food in the cotyledons, the cotyledons shrivel up and drop off.
5. The true leaves of the plant then continue to supply food for the plant by photosynthesis.

IV. How Seeds Travel

A. Seeds grow best when they are scattered far away from the plant that produced them.
   1. If seeds only fell to the ground beside the plant, there would be too many seedlings together, all struggling to live and grow.
   2. Some seedlings would choke each other.
   3. The large number of seedlings would use up most of the minerals in the soil and make the soil poor for growing.
   4. If there should be a condition that was unfavorable for growing, all the seedlings would be killed.

B. Some fruits scatter their own seeds.
   1. Some fruits that grow in pods, like the bean and the pea, twist when they ripen so that the pods break open and scatter the seeds.
   2. Some pods, like the balsam or touch-me-not, burst open at the slightest touch and throw their seeds some distance away.
   3. Tiny holes open in the fruit of the poppy, and, as the poppy stem moves back and forth in the wind, the seeds fly out through the holes.
   4. The witch hazel, pansy, and violet plants also scatter their own seeds.

C. The wind scatters many seeds.
   1. Some seeds, like the milkweed, cottonwood, and dandelion, have fine hairs or tufts that act like parachutes and are carried far away by the wind.
   2. Some seeds, like the maple, ash, elm, and pine, have wings that act like tiny propellers or sails and are also carried away by the wind.
   3. The tumbleweed scatters its seeds as the wind rolls it across the ground.

D. Some seeds, like the coconut, are carried away by water.

E. Birds help scatter seeds.
   1. Mud on the bird's feet may have seeds in it.
   2. Seeds may stick to the bird's bill or feathers and be carried far away.
   3. Some birds eat fleshy fruits, like the cherry, and then drop the seeds to the ground.
   4. Sometimes the birds eat the whole fruit, but the seeds pass through them as waste products and fall to the ground.

F. Animals help scatter seeds.
   1. Squirrels bury nuts, such as the hickory and acorn, in the ground and forget to dig them up.
   2. Many plants, such as the thistle and burdock, produce fruits with stickers that cling to the fur of animals.

G. Man helps seeds travel.
   1. If a wagon or automobile passes through mud that has seeds in it, some of the mud may stick to the wheels and be carried away.
   2. Burrs of the thistle and cocklebur also cling to man's clothes and are carried away.
   3. Seed companies ship seeds to all parts of the world by plane, boat, train, and auto.

V. Uses of Seeds

A. Seeds are used for food.
   1. The most valuable source of food in the world comes from the fruits and seeds of the grasses, such as wheat, corn, oats, rice, and barley.
   2. Peas and beans are used throughout the world for food.
   3. The peanut is used as food, and its oil is used for cooking.
   4. Chocolate and cocoa are made from the

cacao bean, and coffee is made from the coffee bean.
5. The seeds of pepper, mustard, nutmeg, and celery are used as spices.

B. Cotton seeds are used to make cooking oil, and the fibers that stick to the seed are used to make cotton cloth.

C. Oil from the seeds of the coconut tree is used to make soap, candles, and butter substitutes.

D. Seeds from the flax plant produce linseed oil, which is used to make paint, varnish, and other materials.

E. The soybean is used for food in China, but in the United States it has many uses in industry.

PLANTS AS LIVING THINGS

I. Plants Are Living Things

A. Plants are living things, just as animals are.

B. All living things, whether they are plant or animal, are made up of one or more cells.
1. Cells are the smallest living parts of plants and animals.
2. Some tiny plants, such as bacteria, are made up of just one cell.
3. Some tiny animals, such as the ameba, are also made up of just one cell.
4. The human body is made up of many billion cells.

C. Each cell is filled with a living material, called **protoplasm.**
1. Protoplasm is a jellylike material that often feels and looks like the white of an egg.
2. Protoplasm is usually clear, but it can also have tiny bubbles, threads, or grains in it.
3. It is usually colorless, but some protoplasm may appear grey, blue, or brown.

D. Inside the cell, there is a ball-shaped body of heavier protoplasm, called the **nucleus.**
1. The nucleus can be found in the center or at one end of the cell.
2. The nucleus controls and directs the activities of the cell.

E. Each cell is surrounded by a thin covering, called the **cell membrane.**

F. Plant cells are different from animal cells in one way.
1. A plant cell also has a **cell wall,** which surrounds the cell membrane.
2. The cell wall is made up of a nonliving material, called **cellulose.**
3. The cell wall protects the plant cell and makes it stronger.
4. The woody part of a tree is a mass of old, empty cell walls.

G. Not all cells are alike.
1. Many cells have special work to do, so they differ in size and shape, and they may even have special parts.
2. This difference makes it possible for the cell to carry on its special kind of activity or work.
3. For example, the guard cells in a leaf control the opening and closing of the stomata.
4. The bones in an animal are made up of special bone cells.

H. A group of the same kind of cells that carry on the same activity or work is called a **tissue.**
1. The skin of an onion, the pith of a stem, and the bark of a tree are examples of plant tissue.
2. Animals have skin tissue, bone tissue, muscle tissue, nerve tissue, and even liquid tissue such as blood.

I. A group of tissues working together is called an **organ.**
1. The root, stem, leaf, and flower of a plant are all examples of plant organs.
2. The stomach, brain, heart, liver, and

kidneys are all examples of animal organs.

J. All the organs together make up the whole plant or animal.

K. A group of organs that work together in a special activity is called a **system.**

1. Only higher animals have systems.
2. Examples of systems include the digestive and the circulatory systems.

L. Cells, then, carry on all the activities that plants and animals must carry on in order to live.

1. These activities are usually called the **life processes** of plants and animals.
2. The more important life processes of plants include photosynthesis, transpiration, respiration, digestion, circulation, assimilation, growth, excretion, reproduction, and tropisms.

II. Photosynthesis

A. Green plants are especially different from animals in that green plants can make their own food.

B. This making of food takes place mostly in the leaf of the plant, but it can also take place in green stems.

C. The leaf uses two materials to make food: water from the soil and a gas in the air, called **carbon dioxide.**

1. The water, together with dissolved minerals, passes from the soil into the roots, up the stem, and into the leaf.
2. The carbon dioxide in the air enters the leaf through tiny openings, called **stomata,** which are found mostly on the underside of the leaf.

D. In the leaf a green-colored material, called **chlorophyll,** makes it possible for the plant to produce its food.

1. By using the energy of sunlight, the chlorophyll helps the carbon dioxide and water combine to form a sugar, called **glucose,** and a gas, called **oxygen.**
2. Making of food by the plant is called **photosynthesis.**

E. The leaf changes the sugar (glucose) to starch, either immediately or soon afterward.

1. The leaf also changes some of the sugar into fats and proteins.
2. These kinds of food then pass to the stem and roots for use or storage.

F. The oxygen gas is a waste product of photosynthesis, and it passes off into the air through the stomata of the leaf.

III. Transpiration

A. A plant usually takes in more water than it needs.

B. This excess water passes through the leaf's stomata into the air as water vapor.

C. This evaporation of excess water from the plant is called **transpiration.**

D. Two tiny **guard cells** on each side of the stomata control the amount of water that leaves the plant.

1. Usually the guard cells keep the stomata wide open so that water can leave the plant freely.
2. But, when the plant is wilting because it does not have enough water, the guard cells make the stomata smaller, slowing down the evaporation of water from the leaf.

IV. Respiration

A. Plants, as well as animals, need energy to live.

B. They get this energy by using oxygen from the air to burn the food they have made and stored.

1. The air enters the plants chiefly through the small openings (stomata) in the leaves.
2. The oxygen combines with the food to form carbon dioxide and water, and at the same time energy is set free.
3. The carbon dioxide and water are waste products and pass off into the air through the stomata.

C. This energy-freeing process is called **respiration.**

1. Some of the oxygen that is given off in photosynthesis may be used for respiration.
2. Some of the carbon dioxide given off in respiration may be used for photosynthesis.

D. Photosynthesis and respiration are quite different from each other.
1. Photosynthesis is a food-making process; respiration is a food-using process.
2. Photosynthesis stores energy; respiration sets energy free.
3. Photosynthesis uses carbon dioxide from the air and gives off oxygen; respiration uses oxygen from the air and gives off carbon dioxide.
4. Photosynthesis takes place only in cells that have chlorophyll in them; respiration takes place in all cells.
5. Photosynthesis goes on only in sunlight; respiration goes on day and night.

V. Digestion

A. Plants, like animals, prepare their food so that it can be taken in, or absorbed, by the cells.

B. This process is called **digestion.**
1. In plant digestion the food is broken up into very small pieces and then dissolved in the plant fluid, which is called **sap.**
2. After it has been broken up and dissolved, the food is now able to pass through the cell membranes into the cell, where the food can be used.

C. Digestion takes place mostly in the leaf, but it can also take place in other parts of the plant.

VI. Circulation, Assimilation, and Growth

A. Just as with animals, the digested food of plants is carried through tubes to the cells in all parts of the plant.
1. This movement of digested food is called **circulation.**
2. The plant liquid that has the dissolved food in it is called **sap.**

B. Each part of the plant then takes from the sap the food it needs.
1. The food passes through the cell membranes into the cells and is changed into protoplasm (the living material of the cell).
2. The new protoplasm is used to repair worn cells and to grow new ones.
3. This process of changing food into protoplasm is called **assimilation.**

C. Plants also use the process of assimilation to grow in size.

VII. Excretion

A. Like animals, plants get rid of their waste products.
1. In photosynthesis the waste product is oxygen.
2. In respiration the waste product is carbon dioxide.

B. These waste products leave through the stomata of the leaf.

C. This getting rid of waste products is called **excretion.**

VIII. Reproduction

A. Like animals, plants are able to produce new plants of the same kind.

B. This process is called **reproduction.**

IX. Tropisms

A. Although plants cannot move from place to place, as animals do, they can and do move.

B. When the plant is affected by such things as light, water, heat, or gravity, the plant responds by moving either toward or away from the thing affecting it.
1. This plant movement is called a **tropism.**
2. If the plant moves toward the thing that is affecting it, the movement is called a **positive tropism.**
3. If the plant moves away from the thing that is affecting it, the movement is called a **negative tropism.**

C. The response of plants to light is called **phototropism.**
   1. Leaves and stems move toward the light.
   2. This movement is a positive tropism.

D. The response of plants to gravity is called **geotropism.**
   1. Roots grow downward because of the pull of gravity, and this movement is called a **positive geotropism.**
   2. Stems grow upward against the pull of gravity, and this movement is called a **negative geotropism.**

E. The response of plants to water is called **hydrotropism.**
   1. Roots turn in any direction to grow toward water.
   2. They even grow upward against the force of gravity because of this strong hydrotropism.

F. The response of plants to touch is called **thigmatropism.**
   1. The Venus's-flytrap has a leaf that quickly folds in half when touched by a fly or other insect.
   2. The leaves of the mimosa plant turn away from whatever touches them.
   3. Vines, peas, and other climbing plants curl around any firm support.

G. The response of plants to heat is called **thermotropism,** and the leaves of certain plants, like the mimosa, turn away from strong heat.

H. The response of plants to chemicals is called **chemotropism,** and most roots turn toward soil that has a good supply of the chemicals that the plant needs.

X. Annuals, Biennials, and Perennials

A. Plants are divided into three groups, depending upon how long they can live.

B. These three groups are **annuals, biennials,** and **perennials.**

C. Annuals live for only one season.
   1. They sprout or germinate in the spring, grow, produce flowers and seeds, and then die, all in one season.
   2. Annuals usually produce a large number of seeds so that there will be enough seeds to make sure that more annuals will grow the next season.
   3. Examples of annuals include the zinnia, marigold, corn, wheat, bean, and pea.

D. Biennials live for two seasons.
   1. During the first season the biennials grow only roots, stems, and leaves.
   2. The second season they produce flowers and seeds, and then die.
   3. Examples of biennials include the beet, carrot, turnip, hollyhock, and sweet clover.

E. Perennials live for more than two seasons.
   1. Herbaceous perennials, like the daisy, violet, lily, and columbine, die to the ground each year, but their roots stay alive all winter and grow new plants in the spring.
   2. Woody perennials, like trees and shrubs, do not die to the ground, although they usually lose their leaves in the fall and are not active all winter.
   3. The giant sequoia tree is a perennial that can live for hundreds of years.

CARE OF PLANTS AND WAYS OF GROWING THEM

I. Conditions Necessary for Plant Growth

A. Plants need air to grow.
   1. They use carbon dioxide from the air to make food by the process of photosynthesis.
   2. They use oxygen from the air to burn their food and set energy free by the process of respiration.

B. Plants need water to grow.
   1. They use water to make food by the process of photosynthesis.

2. The water also contains dissolved minerals that plants need for making new plant parts and for growing taller.

C. Plants need the proper temperature to grow.
1. Each kind of plant has a certain temperature at which it grows best.
2. Plants have temperature limits beyond which they cannot live.
3. Plants may die if the temperature rises and falls too quickly.

D. Plants need the energy of sunlight to make food and grow.

E. Land plants need soil to grow.
1. Most plants grow best in loam, which is a mixture of sand, clay, and humus (decayed animal and vegetable matter).
2. Some plants grow better in sandy soil and others grow better in clay soil.

F. Plants need chemicals in the soil to grow well.
1. Plants need nitrogen, phosphorus, potassium, calcium, magnesium, and other chemical elements.
2. Some plants grow better when the soil is acid, but most plants grow best when the soil is neutral or slightly alkaline.

G. The cutting or trimming of dead or dying branches from trees and shrubs will help keep the trees and shrubs healthy.
1. This cutting and trimming is called pruning.
2. Live branches are often pruned to give the trees a certain shape or to make the tree produce more fruit and less leaves.

II. Effect of Climate on Plants

A. The climate has a great deal to do with the kinds and amounts of plants that will grow in a certain region.

B. In the tropics there is an abundance of plants because of the high heat and large amount of rainfall.
1. The foliage is dense, and the leaves are broad.
2. Plants grow continuously the whole year around.
3. Such plants as banana trees, date palms, bamboo, orchids, and large ferns grow in the tropics.
4. A greater number and variety of plants grow in the tropics than anywhere else on earth.

C. Very few plants grow in the cold Arctic and Antarctic regions.
1. There are no trees in these regions although a few dwarf willow trees can sometimes be found.
2. Ferns, mosses, lichens, some flowering plants, and grass grow in the very short summer that these regions have.
3. Many of the plants are covered with a sort of hair, and the plants have thick seed coats.

D. A wide variety of plants grow in the temperate climate regions.
1. Oranges, lemons, limes, grapefruit, and cotton grow in regions where the climate is mild and there is little or no frost.
2. All kinds of trees, shrubs, fruits, flowers, and cereal grasses grow in the moderate temperate regions.
3. Evergreens and hardy trees, shrubs, flowers, and grasses grow in cold temperate regions.

E. Not many plants grow in warm desert regions because there is so little rainfall.
1. Desert plants have less leaves, and, consequently, the loss of water from the plant is cut down.
2. The leaves have a thick covering and are often narrower, which also helps cut down water loss from the plant.
3. The mesquite plant sends long roots down to the water table many feet below the surface.
4. The cactus plant has roots that cover a wide area just below the surface, and these roots can quickly take up any rain that falls.
5. Desert plants bloom very quickly, and their flowers have brilliant colors, which immediately attract insects for pollination before the flowers die soon after in the hot sun.

III. Effect of Seasons on Plants

A. Because it is warm all year in the tropics, plants grow through all four seasons.
B. Most plants in the temperate regions grow only in the warm weather of the spring, summer, and fall.
1. Leafy trees, like the oak and the maple, lose their leaves in the fall and stay inactive during the winter.
2. Evergreen trees, like the pine and the spruce, do not lose their leaves in the fall and stay green all winter, but most of the activity in the tree stops.
3. Some nonwoody plants, like the peony and chrysanthemum, die to the ground in the winter, but their roots stay alive and produce new growth in the spring.
4. Other nonwoody plants, like the balsam and zinnia, die completely in the winter, but the seeds they produce will grow new plants in the spring.
C. Plants in the polar regions have a very short growing season because there may be no more than 10 weeks when the temperature is above freezing.

IV. Conservation of Trees

A. The United States has already lost three fourths of its original forests.
B. Early settlers cut down trees to clear the land and farm it.
C. Lumbering companies used the forests unwisely at first.
1. Trees were cut down and allowed to fall on young trees and break them.
2. Brush and branches were left on the ground, where they became dry and burned easily, helping to spread forest fires.
3. Whole forests were cut down without planting new trees to replace those cut down.
D. Forest fires destroy much of our forests.
1. These fires are set in many ways.
2. Some persons set fire to forests deliberately.
3. Persons who burn debris often let the fire get out of control.
4. Smokers sometimes throw lighted cigarettes and matches from automobiles into the forest.
5. Campers leave campfires burning or glowing.
6. Lightning often starts a forest fire.
E. Fungi and insects destroy certain trees in our forests.
1. A fungus has destroyed almost all the chestnut trees in the United States.
2. A fungus carried by a beetle is destroying our elm trees.
3. Another fungus is beginning to kill our oak trees.
F. Grazing and gnawing animals can also destroy our trees.
1. When animals, such as cattle, sheep, hogs, or horses, are pastured in wood lots, the trees eventually disappear.
2. The animals eat or trample young trees and destroy them.
3. They eat the leaves from lower branches, and harm the trunk and roots.
G. Many efforts are now being made to conserve our forests.
H. Lumbering companies are now cutting trees more wisely.
1. They are removing weed trees, crowded trees, crooked trees, damaged trees, and diseased trees so that the trees to be used for timber can grow bigger and healthier.
2. They are cutting down only part of the forest, and then planting new trees that will eventually take the place of those cut down.
I. Spraying diseased trees will stop, or at least check, the spread of the disease.
J. The United States Forest Service, established in 1905, fights and prevents forest fires, develops and recommends better lumbering habits, and finds ways of controlling harmful fungi and insects.
K. Education programs have been developed to lessen man's carelessness in starting forest fires.

V. Conservation of Wild Flowers

A. Our wild flowers are disappearing as more homes and suburbs are built.
B. Persons often destroy wild flowers by picking them carelessly.
   1. Some persons destroy the trailing arbutus plant by pulling up the long trailing stem as they pick the flower.
   2. Others pull up the whole plant instead of just picking the wild flower.
C. Some states are trying to protect their wild flowers by passing laws that forbid the picking of these flowers.
D. Many states establish forest preserves, which allow the wild flowers to grow unmolested.

VI. Ways of Growing Plants

A. There are many ways of growing plants.
B. All plants can be grown from the seeds they produce.
C. Some plants can be grown from roots.
   1. Usually such roots have food stored in them.
   2. The sweet potato, carrot, radish, parsnip, and turnip are roots that can grow new plants.
D. Some stems can grow new plants.
   1. When the stem of a climbing rose plant is made to lie flat on the ground and is then covered with soil, roots will develop at the joints of the stem and grow new plants.
   2. Stems of raspberry bushes can also grow new plants, but, because the roots usually form at the tip of the stem, only the tip is pushed into the ground.
   3. The stems of strawberry plants grow along the surface of the ground, and will form roots at their joints, producing new plants.
E. Plants can be grown from rhizomes.
   1. Rhizomes are long underground stems that grow horizontally close to the surface of the ground.
   2. The iris, lily of the valley, and trillium have rhizomes that can grow new plants.
F. Plants can be grown from tubers.
   1. Tubers are the enlarged tips of rhizomes, in which food is stored.
   2. The white potato is a tuber that can grow a new plant.
   3. The "eyes" of the potato are really buds, from which new growth begins.
G. Plants can be grown from bulbs.
   1. A bulb is a very short underground stem that is surrounded by thick, fleshy, scalelike leaves.
   2. Tulip, daffodil, and onion bulbs can grow into new plants.
   3. A bulb in the ground will form new bulbs around it, and the new bulbs can be separated and used to grow new plants.
H. Plants can be grown from corms.
   1. A corm and a bulb look very much alike, but most of the corm is stem, surrounded by thin, scalelike leaves.
   2. The crocus and gladiolus have corms that grow into new plants.
I. Plants can be grown from cuttings or slips.
   1. A cutting or slip is a piece of stem with leaves on it.
   2. The cutting forms roots when placed in water, wet sand, or wet vermiculite.
   3. The cutting is then transplanted into soil and grows into a new plant.
   4. The geranium, philodendron, coleus, and pussy willow can grow new plants from cuttings.
J. Some plants like the African violet, sedum, and sansevieria can be grown from leaves.
K. Some plants, like phlox, chrysanthemums, and peonies, grow in clumps that can be divided, and the divisions can then be grown in other parts of the garden.
L. Sometimes new plants can be grown by grafting.
   1. In grafting, the twig from one tree is joined to another tree of the same kind.
   2. Grafting is done most often with fruit trees when a grower wants to produce different varieties of the same fruit on one tree.

3. The grower can also save time in growing a certain variety of fruit by grafting twigs of that fruit tree onto a tree that is already growing.
4. Grafting is used to grow such seedless plants as seedless oranges and seedless grapes.

M. Sometimes, new plants can be grown by **budding.**

1. Budding is like grafting except that a bud is used instead of a twig.
2. Budding is used only when a fruit tree is very young.
3. The bud is joined to the tree, and then all the rest of the tree is cut off.
4. The tree now produces only the kind of fruit that would be produced from the bud.

LEARNING ACTIVITIES FOR SECTION ONE: "PLANTS WITH SEEDS"

CLASSIFICATION OF PLANTS

1. *System of plant classification* · Show how the "red delicious" apple tree is classified, tracing the classification step by step from the phylum to the variety itself. Such a classification would appear as shown in Table 13–1.

TABLE 13–1. Classification of Red Delicious Apple

KINGDOM: Plant
PHYLUM: Spermatophyta (all seed plants)
SUBPHYLUM: Angiospermae (flowering plants that produce fruits with seeds)
CLASS: Dicotyledonae (seeds have two cotyledons)
ORDER: Rosales (roses and their relatives)
FAMILY: Rosaceae (produce roselike flowers)
GENUS: Pyrus (produce apple fruits)
SPECIES: malus (cultivated apple trees)
VARIETY: red delicious

2. *The four major plant phyla* · Visit a natural history museum, nearby arboretum, or forest preserve. Look for, examine, and collect specimens or examples of the four major plant phyla.

3. *Gymnosperms and angiosperms* · Have the children examine a conifer tree and a deciduous tree. Note their special characteristics and make a list of their similarities and differences.

4. *Herbaceous and woody plants* · Have the children examine the stems of herbaceous and woody plants, note their special characteristics, and make a list of their similarities and differences.

5. *The parts of a plant* · Make the children aware of the flowering plant as a single living unit. Point out that the plant consists of roots, stems, leaves, and flowers, which produce fruits and seeds. Show the relationship of each part to the whole plant, and list the general functions of each part.

ROOTS

1. *Primary and secondary roots* · Soak some radish seeds overnight. Place a piece of a dark-colored blotter on the bottom of a large, shallow saucer. Wet the blotter thoroughly with water, but do not have any excess water on the blotter. Scatter the seeds on the wet blotter and cover the saucer with a glass square. Place the saucer in a darkened part of the room. The radish seeds will germinate in 2 or 3 days. Keep the blotter moist constantly.

Examine the seeds each day. Note the primary root that grows directly from the seed, and the secondary roots that branch out from the primary root.

2. *Observe root hairs* · Use a magnifying glass to examine the roots grown in Learning Activity 1 above. Look closely at the fuzzy outgrowths at the tips of the primary and secondary roots. These are the root hairs, which absorb water and dissolved minerals from the soil.

3. *Taproots and diffuse roots* · Carefully dig up a dandelion, trying to get the complete root. Also, dig up a small clump of grass. Obtain both the dandelion and grass from a vacant lot, if possible. Note the long taproot of the dandelion and the many shorter diffuse roots of the clump of grass.

4. *Kinds of roots* · Make a collection of actual samples (or pictures wherever the actual examples are unavailable) of fleshy roots, adventitious roots, prop or brace roots, and aerial roots. Label and classify each example, using an index card.

5. *Roots absorb water and dissolved minerals* · Dig up a complete dandelion plant, removing the roots carefully, and gently wash the soil from its roots. If dandelions are unavailable, use plants grown from bean, radish, or tomato seeds instead. Place the roots in a glass jar containing water that has been colored a very deep red with food coloring. In a few hours, or by the next day, the veins of the dandelion leaves will be colored red, because the water and dissolved food coloring will have been absorbed by the roots and then have traveled up to the leaves.

6. *Roots store food* · Display such fleshy roots as beets, carrots, turnips, radishes, and dahlia roots.

7. *Uses of roots* · Make a collection of actual roots, using pictures wherever actual roots are unavailable, showing the different uses of roots. Classify the roots according to their uses, and label each root, describing the purpose for which the root is used.

STEMS

1. *The external structure of a woody dicotyledon stem* · In the late fall or early winter take a field trip to examine the bare twig of a tree. Point out the presence of bark, terminal and lateral buds, bud scales, leaf scars, nodes, and bud-scale scars. Find the exact age of the twig by starting at the present terminal bud and counting the number of bud-scale scars along the twig.

2. *The internal structure of a dicotyledon stem* · With a sharp knife or razor blade obtain a slice of the stem from a herbaceous dicotyledon plant, such as the geranium. Observe the stem under a magnifying glass. Note the presence of the cambium between the outer skin and the central, or woody part, of the stem. Also note how the bundles of hollow tubes are arranged regularly in a circle inside the stem.

Obtain a slice of a good-sized log from a sawmill or a lumber dealer. Note the outer and inner part of the bark, the thin cambium between the bark and the wood, and the sapwood and hardwood. Estimate the age of the tree by counting the number of annual rings. Sand the surface of the log slice until it is smooth, then coat the entire slice two or three times with shellac or varnish, and save it for your science museum.

3. *The internal structure of a monocotyledon stem* · With a sharp knife or razor blade obtain a slice of the stem from a herbaceous monocotyledon plant, such as the lily, tulip, iris, corn, or sugar cane. Observe the presence of only an outer covering and the pith inside the stem. Use a magnifying glass to show how the bundles of hollow tubes are scattered at random throughout the pith.

4. *Kinds of stems* · Make a collection of actual examples (or pictures wherever the actual examples are available) of stems that grow above and below the ground. Label and classify each example.

5. *Stems support the plant* · Take a field trip and point out how stems support the rest of the plant and how the trunk and branches of a tree hold the leaves up to the light.

6. *The stem carries water to all parts of the plant* · Obtain a fresh stalk of celery with some of the leaves still on it, and place it in a glass of water that has been colored a deep red with food coloring (Figure 13–1). With a sharp knife cut off about 1 inch of the bottom of the stalk while the stalk is under the colored water. Allow the celery stalk to stand overnight. Note that the colored water has moved up the stalk and into the leaves. Remove the stalk from the colored water and cut off a section of stalk from the bottom. Note the red color of the hollow tubes in the stem.

7. *Make a two-colored carnation* · Obtain a carnation with a long, thick stem. Split the stem in two parts for a distance of about 3 inches. Place one part in a test tube or glass of water that has been colored with red food coloring, and the other part in a test tube that has been colored with blue or green food coloring (Figure 13–2). Allow the carnation to stand overnight. The flower will have two colors, the color of the various petals depending upon which colored liquid reached them.

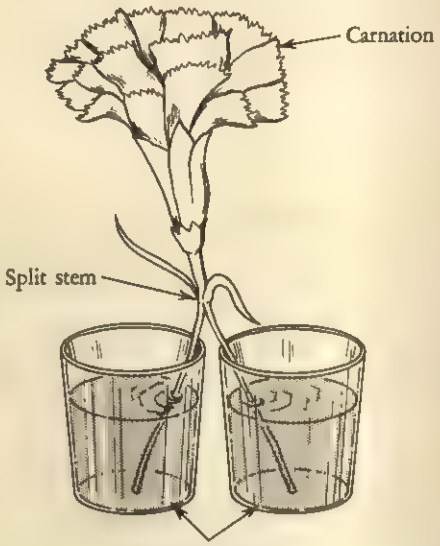


FIGURE 13–2.
A TWO-COLORED CARNATION.

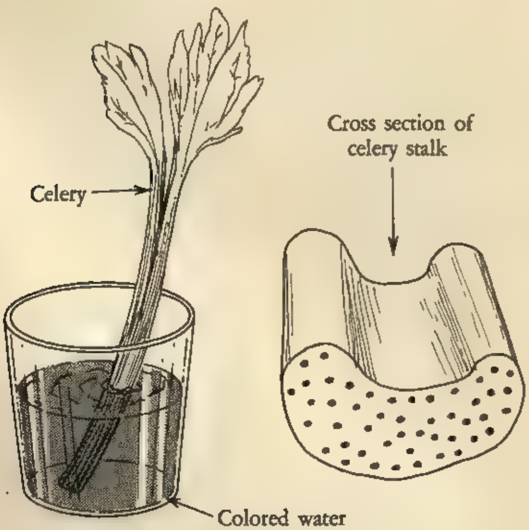


FIGURE 13–1.
COLORED WATER RISES UP THE CELERY STALK.

8. *Uses of stems* · Make a collection of actual stems and pictures of stems, showing their different uses. Classify the stems according to their uses, and label each stem, describing the purpose for which the stem is used.

LEAVES

1. *Collect and examine leaves* · Collect a large variety of leaves to examine their parts, structure, and similarities and differences. Compare their sizes, shapes, edges, and different kinds of vein formation. Also, distinguish between simple and compound leaves. Representative leaves may be preserved by placing the

leaves on a large piece of blotting paper, arranging the leaves so that they do not touch. Cover the leaves with another piece of blotting paper, and then place a board on top of the blotting paper. Weight the board down with heavy books or stones, and let the leaves stay this way until they have dried out thoroughly. The leaves may now be removed and either placed in albums or taped to pieces of construction paper.

2. *Make leaf prints* · Place a leaf veiny side up on some newspapers. Coat the veiny side very lightly with Vaseline and cover the leaf with a sheet of fresh typewriter carbon paper. Place a sheet of white paper over the leaf and rub the side of a round pencil or dowel back and forth several times over the paper. As a result, the leaf will pick up a coating of carbon from the carbon paper. Now place the leaf, this time veiny side down, between two fresh sheets of white paper and again rub the top sheet of paper with the pencil. A silhouette of the leaf will be formed on the bottom sheet, showing the shape and vein pattern of the leaf quite clearly.

3. *Air enters a plant through the leaf* · Fit a flask or narrow-necked jar with a two-hole rubber stopper. In one hole insert a leaf with a long stem, such as the leaf of an African violet. In the other hole insert a piece of glass tubing bent at a right angle or a plastic soda straw bent at an angle (Figure 13–3). Add enough water to the flask so that the stem of the leaf is below the level of the water when the cork is inserted. Now fit the stopper very tightly into the neck of the flask. Use drops of melted paraffin from a burning candle to seal the holes of the stopper containing the glass tubing and stem of the leaf. Suck air from the glass tubing. Air bubbles will come from the end of the leaf stem, showing that air entered the leaf and traveled down the leaf stem.

4. *Observe stomata and guard cells* · Select a leaf from a plant that has soft, tender leaves. Roll the leaf between your hands several times to loosen the bottom epidermis. By using a razor blade or sharp knife, slice or scrape a small piece of epidermis from the underside of the leaf. Place this piece of leaf on a microscope slide, add a drop of water, and cover with a cover glass.

Observe the piece of leaf under a microscope and look for stomata and the surrounding guard cells.

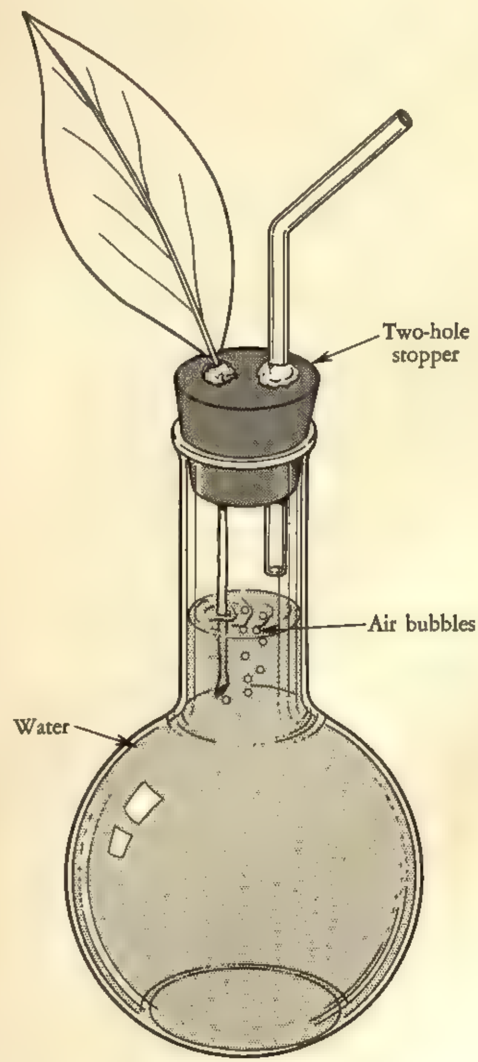


FIGURE 13–3.
AIR BUBBLES SHOW THAT AIR ENTERS THE LEAF AND TRAVELS DOWN THE STEM.

5. *Green leaves contain chlorophyll* • Obtain the water plant elodea from a store that sells aquarium supplies. Examine a leaf of elodea under the microscope and note the green chlorophyll bodies that are present.

You can extract chlorophyll from any green leaf by first boiling the leaf in water for several minutes to break down the plant cell walls. In the winter, a spinach leaf from the grocer can be used. Prepare a double boiler with water in the bottom section and rubbing alcohol in the upper section. Place the leaf in the alcohol and heat the double boiler until the water boils, and then continue to boil for 10 to 15 minutes. The hot alcohol will extract the chlorophyll from the leaf and become dark green.

6. *Leaves need carbon dioxide for photosynthesis* • Obtain a healthy geranium plant. Coat the top and bottom surfaces of one of the leaves with a thin layer of Vaseline. Keep the plant in a sunny location. In a few days the Vaseline-coated leaf will begin to turn yellow. Point out that the Vaseline prevented carbon dioxide in the air from entering the leaf's stomata, and this lack of carbon dioxide stopped the process of photosynthesis in the leaf.

7. *Leaves need sunlight for photosynthesis* • Repeat Learning Activity 5 above, but this time cover one of the leaves completely with aluminum foil. The leaf will turn yellow because the aluminum foil prevents sunlight from reaching the leaf, and this failure to receive sunlight stops the process of photosynthesis.

8. *Leaves produce starch during photosynthesis* • Expose a soft-leaved plant, such as a geranium, to the sun for several hours so that photosynthesis can take place. Pluck one of the leaves and boil it in water for several minutes to break down the cell walls in the leaf. Prepare a double boiler with water in the bottom section and rubbing alcohol in the top section. Place the leaf in the alcohol, heat the double boiler until the water boils, and continue to boil for 10 to 15 minutes (or longer if necessary) until the alcohol extracts most of the chlorophyll from the leaf.

Remove the leaf from the alcohol and rinse it in hot water. Place the leaf in a large, shallow saucer and dry the leaf by blotting gently with cleansing tissue. Place a few drops of tincture of iodine on the leaf. A dark blue or purple color will form after a few minutes, and this color shows the presence of starch in the leaf. You can prove that the dark blue color is a test for starch by adding a few drops of iodine to some corn starch or to a slice of potato.

9. *Leaves give off oxygen during photosynthesis* • Obtain a water plant, such as elodea or sagittaria, from a store that sells aquarium supplies. Place the water plant in an aquarium filled with water, and place a short-stemmed glass or plastic funnel over the plant. Fill a test tube with water and invert the test tube, still full of water, over the stem of the funnel (Figure 13–4). Make sure there are no air bubbles in the test tube at this time. Now place the aquarium in a sunny place for sev-

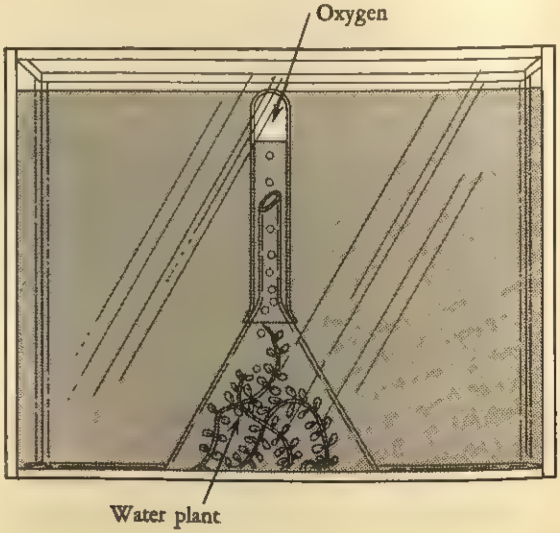


FIGURE 13–4.
THE WATER PLANT GIVES OFF BUBBLES OF OXYGEN DURING PHOTOSYNTHESIS.

eral days. The water plant will give off bubbles of oxygen, which will displace the water in the test tube. After the bubbles have displaced most of the water, remove the test tube and hold it mouth upward. Quickly place a glowing splint inside the test tube. The oxygen gas in the test tube will make the splint either glow more brightly or burst into flame.

10. *Leaves give off water* · Obtain a potted geranium plant and a wooden stick or dowel about the same length as the flower pot and plant combined. Place the stick in the soil so that the top of the stick extends slightly above the plant. Cover the soil and the sides of the flower pot with aluminum foil. Now place a plastic bag over the plant and tie the mouth of the bag securely around the stem (Figure 13–5). Prepare a control by duplicating every condition except the presence of the geranium plant. Such a control involves having the same size flower pot, same amount of soil and moisture in the soil, same size wooden stick, aluminum foil over the soil and sides of the pot, and the same size plastic bag over the stick and tied around the stick.

Now place both flower pots in the sun for a few hours. A large amount of water droplets will appear on the inside of the plastic bag covering the geranium plant. Point out that covering the soil and sides of the flower pot eliminated the possibility of the water coming from the soil or through the porous pot. Because no water droplets appeared in the control, the water could not have come from the air, which usually contains water vapor. Therefore, the water droplets could only have come from the plant itself.

FIGURE 13–5.
A CONTROLLED EXPERIMENT TO SHOW THAT LEAVES GIVE OFF WATER.

11. *Leaves change color in the fall* · When the leaves begin changing color in the fall, note the changes in color and associate the change in color with the kind of tree. Point out that the colors appear when the leaves stop making chlorophyll. This fact can be demonstrated by obtaining two plants of the same kind and size. Allow one plant to stay in the sunlight all day. Keep the other plant in a dark closet for half the day or more if necessary. After a few days note the yellowish appearance of the leaves that had less sunlight. These leaves now have less chlorophyll in them as well, and the yellow pigment in the leaves has begun to show.

12. *Uses of leaves* · Make a collection of actual leaves, using pictures wherever actual leaves are not available, showing the different uses of leaves. Classify the leaves according to their uses, and label each leaf, describing the purpose for which the leaf is used.

FLOWERS

1. *Study the parts of a flower* · Obtain a large simple flower, such as a tulip, lily, gladiolus, petunia, or sweet pea. Examine the flower closely (Figure 13–6). Observe the flower stalk and its upper larger part, the receptacle. At the base of the receptacle note the sepals that surround the petals. In the tulip and the lily the sepals are the same color as the petals. Use tweezers to remove the sepals and petals and place them on separate pieces of paper,

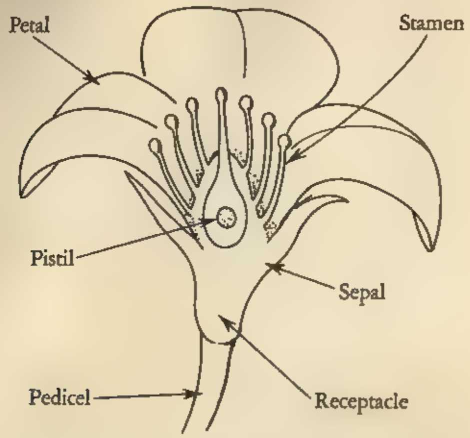


FIGURE 13–6.
DIAGRAM OF THE PARTS OF A FLOWER.

appropriately labeled. Count the number of sepals and petals.

Observe the stamens surrounding the pistil in the center of the flower. Count the number of stamens, remove them with the tweezers, and place them on a labeled piece of paper. Examine the stamens with a magnifying glass. Locate the filament and anther, and observe the pollen that may be present on the anther. Remove the pistil and observe the stigma, style, and ovary under the magnifying glass. With a razor blade or sharp knife cut through the ovary lengthwise. Observe the ovules with the magnifying glass and try to count the number present.

Have the children make a large drawing or diagram of the whole flower and its individual parts. Label the parts of the flower and also the parts of the pistil and stamen.

2. *Kinds of flowers* • Have the children observe examples, pictures, or drawings of different kinds of flowers. Note the basic difference between complete and incomplete flowers, perfect and imperfect flowers, and monocotyledon and dicotyledon flowers. Point out that the flower parts of monocotyledon plants are in threes or multiples of three whereas the flower parts of dicotyledon plants are in fours and fives or their multiples. Also, the sepals and petals of monocotyledon flowers are often the same color.

Obtain a composite flower such as a daisy, dandelion, chrysanthemum, zinnia, marigold, sunflower, or aster. Pull out a ray flower (petal) and a disk flower (little tube in the center), and examine them with a magnifying glass. Do the ray flower and disk flower have all the parts of a perfect flower? What parts, if any, are missing?

3. *Observe pollen grains* • Place a drop of water on a microscope slide. Shake pollen from a flower on the drop and cover with a cover glass. Examine the pollen under a microscope.

4. *Germinate pollen grains* • Pollen will germinate in a solution containing the right proportions of sugar in water. Fill three cups with boiled water. Add 1 teaspoon of sugar to one cup, 2 teaspoons of sugar to the second cup, and 3 teaspoons of sugar to the third cup. Stir the water in each cup until all the sugar is dissolved. Now pour a portion of the sugar solutions into shallow saucers. Shake pollen for different kinds of flowers on the surfaces of the sugar solutions. Cover each saucer with a piece of glass and let the solutions stand at room temperature for several hours. Examine the pollen grains with a magnifying glass to see if tubes are growing from them. If nothing is visible, place a drop of the sugar solution on a microscope, cover with a cover glass, and examine under a microscope.

5. *How flowers are pollinated* • Obtain flowers that have a good amount of pollen on their anthers. Blow vigorously on the anthers, creating a "wind" that blows the pollen away. Have the children observe or recall how bees and insects travel from flower to flower looking for nectar. Observe the shapes of flowers that are visited by bees and other insects. Point out that the stamens and pistils of the flower are positioned so that, when the insect obtains the nectar, it must pick up some of the pollen from the stamens and at the same time rub against the pistil. When the insect travels to

other flowers, it touches the pistil again, and in this way it deposits some of the pollen that clings to its hairy body.

6. *Fertilization and development of flowers into fruit* · Collect flowers at different stages in their growth and maturity, ranging from freshly opened buds to those where all the petals have fallen off. Cut open the ovary of each and observe what changes have taken place. Two excellent flowers to observe are the iris, which has hundreds of ovules in its ovary, and the rose, which forms a sizable fruit after it has been fertilized.

Obtain a quantity of fresh string beans or peas, and open some of the pods that do not seem to be completely filled. The tiny, seed-like parts are the remains of ovules that were not fertilized by pollen, and so did not develop into beans or peas.

7. *Selective breeding* · Have the children read about and report on how the selective breeding of flowers is conducted. The work of Luther Burbank should be of interest to many children.

FRUITS

1. *The definition of a fruit* · Write a list of well-known fleshy and dry fruits on the chalkboard. Point out that to a scientist the word "fruit" means the ripened ovary from any flowering plant. As a result, all our vegetables and cereal grains are fruits. Flowers, shrubs, and flowering trees also produce fruits.

2. *Parts of a fruit* · Give the children a list of foods and ask them to tell you if, when eating these foods, they eat the whole fruit, just the fleshy part, or just the seed. Include such common items as the apple, peach, grape, pineapple, raspberry, strawberry, banana, tomato, cucumber, squash, hickory nut, pumpkin, pea, green bean, lima bean, and string bean. Have the children classify each of these fruits.

3. *Kinds of fruits* · Display or show pictures of specific examples of pomes, drupes, berries, dehiscent pod fruits, dehiscent capsule fruits, and indehiscent fruits. Describe how each fruit was formed, its parts, and the number and kind of seeds inside.

4. *Compare a peach seed and an almond* · Obtain a peach stone and an almond in the shell. Compare the appearance of the two stones. Break open the peach stone with a hammer, and crack open the almond. Compare the size, shape, and taste of both seeds. Point out that the almond is also the hard stone of a fleshy fruit, but in this case the flesh is thrown away without being eaten and the stone is saved.

5. *Selective breeding of fruits* · Take a field trip to an experimental farm and have the horticulturist show and explain how cross-pollination and grafting are used to produce tastier, larger, and hardier fruits. If a field trip is not feasible, invite the horticulturist to visit the children instead.

Consult the yearbooks of the United States Department of Agriculture for articles on hybrid corn. Seed-corn companies also produce literature on hybrid corn and how it is grown. Your county agricultural agent will give you a list of the names and addresses of such companies.

SEEDS

1. *Parts of a seed* · Soak a lima bean in water overnight. Remove and examine the transparent seed coat. Separate the two seed leaves. Examine the tiny embryo that is attached to one of the seed leaves, using a magnifying glass. Repeat the learning activity, this time using a kernel of corn. Note the presence of only one seed leaf.

2. *Seed leaves contain food for germinating plants* · Soak some lima beans, peas, and kernels of corn overnight, remove the seed coats,

and mash the seeds thoroughly. If you like, you may grind the dried seeds, and then add a little water to the flour and stir to form a paste.

Add a few drops of tincture of iodine to some of the ground seeds. The seeds will turn a deep purple, showing the presence of starch.

Put some of the mashed seeds in a test tube. Add a small amount of nitric acid, boil for a few seconds, and then add enough ammonia to neutralize the nitric acid. If protein is present, the nitric acid will turn the solution a bright yellow, and the ammonia will change the yellow color to orange.

Rub a piece of walnut meat vigorously on a piece of white or brown paper. Warm the paper over a hot plate, but do not set the paper on fire. Then hold the paper up to the light and note the grease spot, showing the presence of fat.

When seeds sprout, the starch is changed to sugar. Mash some sprouting seeds, add a small amount of water, stir, and transfer to a test tube. Obtain some Benedict's solution from the drugstore, pour a small amount into the test tube, and heat. If sugar is present, the solution will turn a greenish-yellow and then a deep orange or brick red color.

3. *How seeds germinate* · Obtain some lima beans and kernels of corn from the seed store. Do not use grocery store seeds because they may be immature or heat-treated, and so may not germinate. Line a water tumbler with a rectangular piece of dark-colored blotter, and stuff absorbent cotton or peat moss into the tumbler to keep the blotter tight against the sides of the tumbler (Figure 13–7). Soak the lima beans and corn kernels overnight and slip a few of each between the blotter and the sides of the tumbler. Moisten the cotton and keep it moist throughout the experiment to make sure the blotter is always moist. Place the tumbler in a warm place away from direct sunlight. Observe the tumbler each day and note the way the seeds germinate. Continue the germination until the seeds are well sprouted.

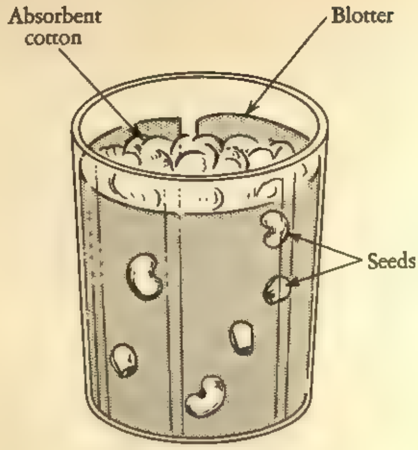


FIGURE 13–7.
A TUMBLER SEED GERMINATOR.

4. *Conditions necessary for germination* · Prepare eight of the "tumbler gardens" described in Learning Activity 3 above. Place one tumbler in the dark and one in the light (but not in direct sunlight). The seeds will germinate just as well in the dark as in the light. Point out that light is not necessary for germination and, in some cases, may even be harmful. However, once the plant has germinated and forms leaves, it needs light to grow.

Keep one tumbler watered regularly, and refrain from giving the other tumbler any water at all. The seeds in the dry tumbler will not germinate.

Cover one tumbler tightly with plastic, such as Saran Wrap, and keep the other tumbler continually exposed to the air. The seeds in the covered tumbler will not sprout because they need air to germinate.

Place one tumbler in the refrigerator and keep the other tumbler at room temperature. The seeds in the cold tumbler will not germinate because they need warmth to germinate

Obtain three flower pots of the same size. Fill one pot with sand, the second with clay, and the third with rich soil containing humus. Soak some lima beans or radish seeds overnight, and then plant two or three seeds in each pot. Keep all three pots at the same temperature and give all of them the same amount of water.

Although the seeds in all three pots may germinate, the plants in the pot containing the rich soil will eventually be taller and sturdier.

5. *Testing seeds for germination* · Obtain a batch of radish seeds from the seed store. Soak 50 of them overnight, and obtain a piece of cotton flannel cloth about 12 inches square. Moisten the flannel cloth and place the radish seeds on the flannel. Roll the flannel into a loose roll and place it in a shallow pan. Keep the flannel moist and warm for a week, and then unroll the flannel carefully and count the number of seeds that have germinated. The number of germinated seeds divided by the total number of seeds (50), multiplied by 100, will give you the percentage of germination. Repeat the experiment using bean, corn, and tomato seeds.

6. *Germinating seeds give off carbon dioxide gas* · Obtain 20 or 30 lima beans from the seed store and soak them overnight. Put the seeds in a flask or narrow-necked jar and add enough water to cover about half of the seeds. Fit the flask with a two-hole rubber stopper. In one hole insert a thistle tube and let the tube extend to just above the bottom of the flask. In the other hole insert a glass tube that leads to a water tumbler (Figure 13–8). Allow the beans to stay in the flask for a day or two. Then pour fresh limewater, which can be obtained from the drugstore, into the tumbler. Pour water slowly into the thistle tube until the flask is half-filled. The water will force the carbon dioxide, which is now above the seeds, through the glass tubing and into the limewater, making the limewater turn milky. You can first show that carbon dioxide turns limewater milky by bubbling air from your lungs into limewater through a soda straw.

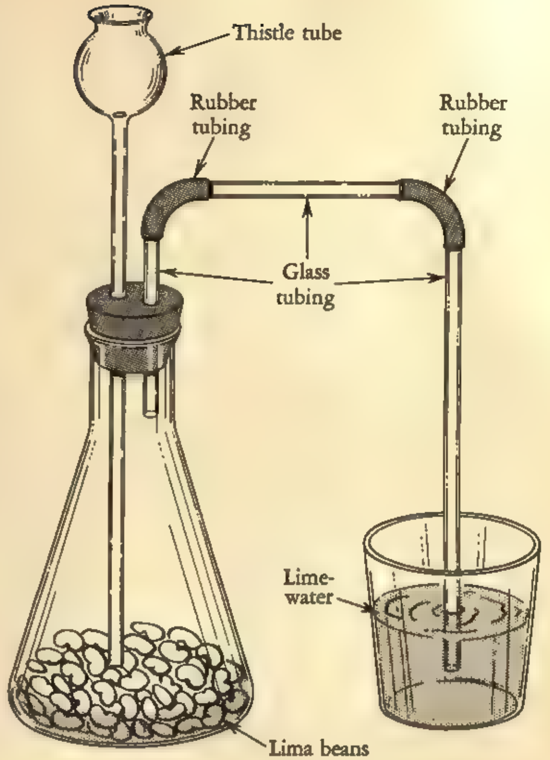


FIGURE 13–8.
WHEN SEEDS GERMINATE, THE CARBON DIOXIDE GAS THEY GIVE OFF CAUSES LIMEWATER TO BECOME MILKY.

7. *Observe the rate of seed growth* · Obtain some radish seeds from a seed store, soak them overnight, and then plant them in a flower pot filled with soil. Water the pot regularly and wait until the tiny plants begin to appear above the soil. Obtain two squares of glass about 1 foot long and 1 foot wide, and insert a piece of dark-colored moist blotter between them. Each day, for 10 to 14 days, carefully remove one entire radish plant from the soil and place it on the moist blotter. You can keep the panes of glass together with string or rubber bands. Keep the blotter moist at all times. At the end of 2 weeks you will have a clear-cut record of the daily growth of the radish seeds.

8. *How seeds travel* · Collect seeds (or pictures, if seeds are unavailable) that will illustrate some of the ways that seeds travel. Discuss methods of seed travel, and list on the chalkboard all the possible ways that seeds travel.

9. *Uses of seeds* · Make a display collection of seeds, using pictures when actual seeds are

not available, showing the different uses of seeds. Classify the seeds according to their uses, and label each seed, describing the purpose for which the seed is used.

PLANTS ARE LIVING THINGS

1. *Examine plant cells* · Slice an onion into rings. Discard the first two outer layers. Tear off the thinnest possible piece of skin from the third layer. Place a portion of this skin on a microscope slide, add a drop of water and a drop of tincture of iodine, and cover with a cover glass. Soak up any excess liquid by placing the tip of a blotter against the edges of the cover glass. The iodine stains the onion cells and makes them stand out very clearly. Examine the onion cells under the microscope. The tip of the aquarium plant elodea also can be used to observe plant cells.

2. *Photosynthesis* · Repeat Learning Activities 3–9 of "Leaves" (pp. 459–460) to show that photosynthesis is a life process of plants.

3. *Transpiration* · Repeat Learning Activity 10 of "Leaves" (p. 461) to show that transpiration is a life process of plants.

4. *Plant respiration* · Place a gallon-size, wide-mouthed glass jar over a small potted plant (Figure 13–9) and keep the plant in darkness for a day. Remove the glass jar, quickly add a cup of limewater (which can be obtained from the drugstore) to the jar, cover the jar, and shake well. The limewater will turn milky, showing the presence of carbon dioxide. Point out that the carbon dioxide was formed during the process of respiration that took place in the plant during the period of darkness.

5. *Circulation in plants* · Repeat Learning Activity 5 of "Roots" (p. 457) and Learning Activity 6 of "Stems" (p. 458) to show that circulation is a life process of plants.

FIGURE 13–9.
PLANTS GIVE OFF CARBON DIOXIDE DURING RESPIRATION.

6. *Growth of plants* · Repeat Learning Activity 3 of "Seeds" (p. 464) to show that growth is a life process of plants.

7. *Plant excretions* · Repeat Learning Activities 9 and 10 of "Leaves" (p. 460) and Learning Activity 4 above to show that excretion is a life process of plants.

8. *Plants respond to light* · Select a potted plant, such as a geranium, whose leaves already face the sunlight. Turn the pot around so the leaves now face away from the window. In a few days the leaves will again turn toward the light. Fast-growing plants, such as radish plants, will turn toward the light very quickly.

9. *Plants respond to gravity* · Grow a "tumbler garden" by repeating Learning Activity 3 of "Seeds" (p. 464). However, after the seeds have germinated and produced noticeable roots,

give one or two of the seeds a half turn so that the roots face up and the stem faces down. Note how the roots and stem change the direction of their growth accordingly. The roots respond positively toward the pull of gravity, and the stems respond negatively away from the pull of gravity.

10. *Plants respond to water* • Cut off one side of a waxed cardboard carton, such as a milk carton, to make a trough for holding soil. Cut a rectangle from another side of the carton and tape a piece of glass or some clear plastic or cellophane over the hole on the inside of the carton to produce a window (Figure 13–10). Punch a few holes in the bottom of the carton for drainage, cover the holes with flat rocks, and fill the carton with soil. Obtain some lima beans from a seed store and place them about 1 or 2 inches into the soil beside the plastic or cellophane so that their germination and root growth will be visible. Place the carton in a shallow pan and water the soil regularly until the beans have germinated into growing plants. Now water the soil at one end of the carton only. In a week or two you will see the roots turned toward the direction of the water.

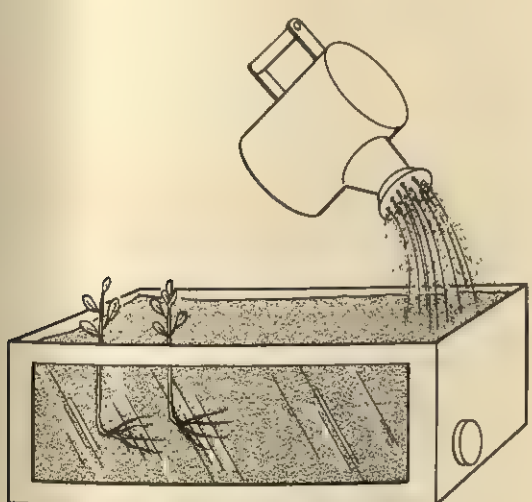


FIGURE 13–10.
ROOTS TURN TOWARD WATER.

11. *Climbing plants twist in a counterclockwise direction* • Grow two or more twining plants, such as a morning glory or a pole bean plant. Insert a long, thin, round stick or dowel into each of the pots for the plants to twine around. Allow only one tendril in each plant to twine around the stick. The tendrils will twine in a counterclockwise direction. Try twining one of the tendrils around the stick in a clockwise direction. In a few hours the tendril will unwind itself.

12. *Some plants are sensitive to touch and heat* • Obtain some mimosa seeds from a seed order house, a scientific supply house, or from someone that teaches in the South. Plant the mimosa seeds and cultivate them until they grow about 6 inches high. Now pinch one of the top leaves, or stroke it gently a few times. The leaf will droop, and will not regain its original shape for several hours.

Next, strike a match and let it burn for a second or two. Blow out the match and touch one of the leaves with the warm tip of the match. The leaf will droop, and will not regain its original shape for several hours.

13. *Annuals, biennials, and perennials* • Show examples or pictures of well-known annuals, biennials, and perennials, and trace the life cycles of each, using simple diagrams if necessary.

14. *Make a woodland or desert terrarium* • A terrarium is a place where plants and animals may live under conditions similar to those of nature. Obtain a large rectangular aquarium. Cover the bottom with about 1 inch of small gravel. On top of the gravel spread about 2 inches of a mixture of three parts of humus to one part of sand, and water thoroughly. Bury small pieces of charcoal into the gravel and humus. If you like, add more soil to one part of the aquarium to simulate a small hill. Embed a pie tin into another part of the soil, and fill the tin with clear pond water or with tap water that has been allowed to stand for 24 to 48 hours. Add a rock or two and some pieces of

bark. Now plant small ferns and mosses in the soil. You can place a tree frog, turtle, newt, and chameleon in the terrarium. If you have a chameleon or tree frog, insert a piece of branched wood for climbing. Now cover the terrarium with a glass plate that is slightly raised with rubber or cork pads to allow free circulation of air. Your woodland terrarium is now complete. Do not overwater the terrarium because the air inside the terrarium will be quite moist, and water will condense on the inside of the glass. Keep the temperature of the woodland terrarium constantly between 65 and 72 degrees Fahrenheit. A pet shop will provide you with the right food for each animal.

To make a desert terrarium, cover the bottom of the aquarium with about 2 inches of a mixture of equal parts of sand and humus. Cover this mixture with about ½ inch of fine sand. Add a few rocks, and embed a shallow saucer containing water until its top edge is level with the surface of the sand. Plant small cacti or yuccas in the soil, moistening the roots before planting and sprinkling the surface with water after planting. You can place a horned toad, collared lizard, and small desert snake in the terrarium. Cover the top of the desert terrarium with a fine wire screen rather than a glass plate. Water lightly just once a week, but keep the saucer of water full at all times. Keep the temperature of the desert terrarium constantly between 68 and 85 degrees Fahrenheit. The horned toad, lizard, and snake will eat insects, worms, and small live animals such as toads and frogs.

CARE OF PLANTS AND WAYS OF GROWING THEM

1. *Conditions necessary for plant growth* · Obtain five potted plants, all the same kind and about the same size. Place one in a dark closet and another in the refrigerator. Cover the leaves of the third plant with a thin layer of Vaseline to keep air from entering the plant. Do not water the fourth plant, and use the fifth plant as a control. Water all plants regularly, except the one that has been designated to receive no water. After a few days, note the effect of darkness, cold, no air, and no water on the growth of the plants.

Plant two or three seeds in separate pots containing sand, clay, and soil rich with humus. Water all three pots regularly and equally. Although the seeds in all three pots may germinate, the plants containing the rich soil will eventually be taller and sturdier.

2. *Effect of climate on plants* · Have the children read about and report on the kinds and amounts of plants that will grow in tropical, temperate, and arctic regions.

3. *Effect of seasons on plants* · Have the children observe, recall, or read about what happens to plants during the different seasons of the year.

4. *Conservation of trees* · Have the children read about and report on how forest fires, unwise lumbering practices, insects, and grazing and gnawing mammals can destroy our trees. Write to the United States Forest Service, Washington 25, D.C., for materials on conservation of plants and trees. Make a list of good and bad practices for the use of fire in forests and wooded areas. Collect and display pictures showing forest fires and other kinds of destruction of trees.

5. *Conservation of wild flowers* · Show pictures of wild flowers that are protected by state conservation laws. Because so many wild flowers grow very slowly, point out that overpicking these flowers will make them very rare or even extinct.

6. *Grow a plant from a seed* · Have the children grow plants from a variety of seeds, including radish, lima bean, corn, grapefruit, and orange seeds. Although most tree seeds are small and germinate slowly, the avocado seed is an exception. Place the avocado seed, pointed end up, into a tumbler of water so that one third of the seed is submerged. Insert three

sturdy toothpicks horizontally into the seed at different positions, and let the toothpicks rest on the lip of the tumbler so that they hold the seed in position. Put the tumbler in a warm, dark place, and in a very short time white roots will appear, followed by a vigorous tall shoot. Place the plant near a window. After 6 or 7 weeks it may be transplanted in sandy soil.

7. *Grow a plant from a root* · Place a large sweet potato, narrow end downward, into a large, wide-mouthed glass jar of water so that the lower third is submerged. Hold the sweet potato in position by inserting three wooden meat skewers or pointed sticks horizontally into the sides of the sweet potato, and resting the skewers on the lip of the jar (Figure 13–11). Put in a dark, warm place. When roots and stems appear, move the plant to sunlight. Add more water whenever necessary. A large sweet potato will produce a pretty plant that will live for almost the entire school year.

Plants will also grow from the tops of carrots, beets, turnips, and pineapples that still have foliage on them. Cut off the top inch or two, and place this top portion in a shallow dish of water.

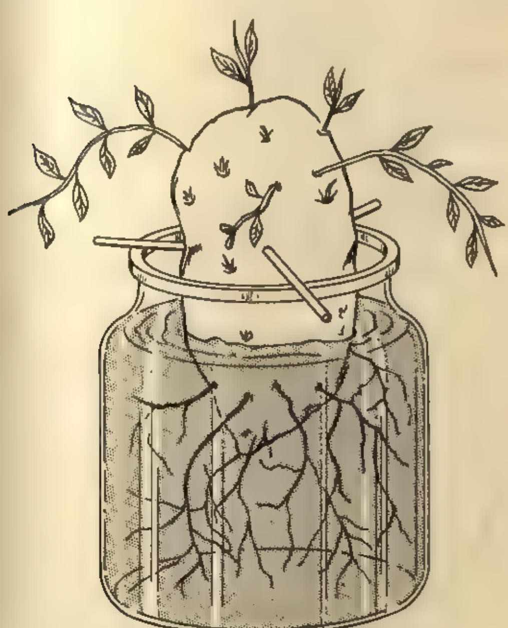


FIGURE 13–11.
GROWING A PLANT FROM A SWEET POTATO.

8. *Grow a plant from a stem cutting* · Cut off a stem from a philodendron, coleus, or English ivy plant. Remove all but the top three or four leaves, and place the base of the stem in a tumbler of water. Keep the plant away from direct sunlight until a good root system has developed. Then transplant the stem into soil.

Repeat the process, using a geranium or begonia stem, but this time place the stem in moist sand. When roots are formed, transplant the stems into soil. The same procedure can be conducted with an African violet, using just one leaf and its stem.

9. *Grow a plant from a rhizome* · Obtain an iris from a greenhouse or select one from an old clump that has been dug up and divided. Plant the iris in soil, with the rhizome about 1 inch below the level of the soil. Water regularly, but do not overwater.

10. *Grow a plant from a tuber* · Obtain a white potato, preferably one that has begun to sprout, and submerge it halfway into a glass jar of water. Hold the potato in position with wood meat skewers or toothpicks, as described in Learning Activity 7 above. Put in a dark, warm place. When roots and leaves appear (in 2 or 3 weeks), move the plant to sunlight. The white potato will not be as dense or live as long as the sweet potato plant.

11. *Grow a plant from a bulb* · Place pebbles in a shallow saucer and add water. Insert a narcissus bulb, pointed end up, into the pebbles so that only the thickest part of the bulb is covered. Keep the saucer in a cool, dark place until roots form, and then move it to a bright or sunny area. Water as often as is necessary to keep the bulb moist.

12. *Grow a plant from a leaf* · Fill a large flower pot with sand, and then water until the sand is quite moist. Select a good-sized begonia

or African violet leaf and make several large cuts across the large veins on the veiny side of the leaves, using a razor blade or a sharp knife. Place the leaf, veiny side down, on the sand and carefully press down so that the cut edges of the veins are in close contact with the sand. Place a few small pebbles on the leaf to hold it down. Cover the pot with a piece of glass to prevent the water from evaporating too quickly, and water regularly as needed to keep the sand moist. In 2 or 3 weeks small roots will grow from the cuts in the veins. Soon after, a stem will begin to grow. Remove the glass cover, water regularly until the roots and stem are well developed, and then transplant into rich soil.

Sansevieria ("mother-in-law's tongue") and sedum leaves will produce new plants very easily. Just cut a leaf into sections 4 to 6 inches long, and place one or more sections in well-drained soil. The sections will root and grow.

13. *Grafting and budding* · Have the children read about and report on how new plants can be grown by grafting and budding. Wherever possible, use actual demonstrations, films, or pictures showing these processes. Discuss the purpose and value of using these techniques.

SECTION TWO: Plants Without Seeds

ALGAE

I. What Algae Are

A. Algae are the simplest green plants, and have no roots, stems, and leaves.

B. They are members of a large group, or **phylum**, of plants called **Thallophytes.**

C. The cells of all algae contain chlorophyll, so the algae are able to make their own food by photosynthesis, just as seed plants do.

D. Although all algae contain green-colored chlorophyll, many algae also have other pigments that hide the green chlorophyll color.

1. When classifying algae, biologists usually name them by their color, although the algae are really classified by their structure.
2. On the basis of color classification, there are five common groups of algae: **blue-green, green, golden brown, brown,** and **red** algae.

II. Structure of Algae

A. Many algae are made up of just one cell.

1. Some seem to swim about like animals.
2. Others float in the water or settle to the bottom.

B. Many algae form colonies, which are made up of many one-celled algae.

1. All the algae that make up a colony are attached to each other.
2. Yet each lives independently and does not have to depend on other algae for anything.

C. Many algae look like threads, called **filaments,** which are also attached to each other to form colonies.

D. Many kinds of algae have a jellylike cell covering.

1. This covering protects the cell from losing water and from unfavorable conditions.
2. These coverings make the algae feel

slimy, and the algae are hard to grasp when in the water.

III. How Algae Reproduce

A. Algae can reproduce in many ways.
B. All of them can reproduce by **fission,** in which a cell divides into two parts.
  1. When a one-celled alga divides, two new algae are formed.
  2. When the algae in a colony reproduce by fission, the colony becomes larger because all the new algae are connected to the older ones and to each other.
C. Many algae reproduce by forming small bodies, called **spores.**
  1. At first the spores swim around freely like tiny animals.
  2. Later, they settle against some object.
  3. Some spores form new algae immediately.
  4. Other spores remain quiet for weeks or months until conditions are right, and then they form new algae.
D. Some algae produce sexual cells, called **gametes.**
  1. The male cell is called a **sperm.**
  2. The female cell is called an **egg.**
  3. The male and female cell unite to form a mass, called a **zygote.**
  4. Some zygotes form new algae immediately.
  5. Other zygotes remain quiet for a time, and then form new algae.

IV. The Blue-Green Algae

A. The blue-green algae are found in fresh water and in salt water.
B. They can be found in almost every stream, pond, or ditch.
C. They are usually found in colonies.
D. Most of them are blue-green in color, although some look almost black, and one kind is even reddish-brown.
E. They usually reproduce by fission.
F. They grow best in the summer.
  1. Some of them color the water.
  2. Others give the water a fishy odor and taste.

V. The Green Algae

A. The green algae are found in fresh water, in salt water, and on land.
B. Some green algae are one-celled, whereas others form large colonies.
C. Their color ranges from bluish-green to yellowish-green.
D. Some reproduce by fission, others by spores, and still others by sexual cells (gametes).

VI. The Diatoms

A. Diatoms are tiny, one-celled algae that are usually golden brown in color, although some are yellow-green.
B. They have all kinds of shapes, and can be round, oval, triangular, rectangular, spindle-shaped, or boat-shaped.
C. Their cell walls are filled with a glasslike material, called **silica.**
  1. The cell wall is in two parts, which fit together, one over the other, like the halves of a little box.
  2. The cell walls have beautiful designs on them.
D. The diatoms reproduce by fission.
E. When diatoms die, their shell-like walls fall to the bottom of the ocean or pond and pile up into masses.
  1. These masses are scooped up, cleaned, and refined.
  2. They are then used in toothpastes and powders, scouring powders, blackboard chalk, and other materials.

VII. The Brown Algae

A. The brown algae are found in salt water, usually near the seashore.
B. Some are very small, but others can be as long as 150 feet.
C. Some of the larger brown algae are attached to rocks along the seacoast, and

these algae are more commonly called kelp or seaweed.

1. They have air bladders with air in them, which help keep the plant afloat.
2. They have a cuplike part, called a **holdfast**, which holds the plant fast to the rock.
3. They are used as packing around lobsters, crabs, oysters, and clams when these seafoods are shipped to different parts of the country.

D. Some of the larger brown algae float freely in water.

1. These algae also have air bladders that keep the plants afloat.
2. Sometimes these plants cover hundreds of square miles of water, as in the Sargasso Sea in the North Atlantic Ocean.

E. The smaller forms of brown algae usually reproduce by fission or by spores, but the larger forms usually reproduce by sexual cells (gametes).

VIII. The Red Algae

A. The red algae are found mostly in salt water, and most of them are small.

B. They always grow attached to a solid object.

C. Some grow in shallow water, and others grow in deeper water.

D. Some reproduce by fission, others by spores, and still others by sexual cells (gametes).

IX. Uses of Algae

A. Algae are the chief source of food for many of the animals that live in the water.

B. Because algae have chlorophyll and carry on photosynthesis to make their own food, they give off oxygen, which water animals need to live.

C. Seaweeds are used by man for fertilizing the soil.

D. Algae are used in some parts of the world to make soups and gelatins.

E. Algae are used in ice cream to make it smooth, and in salad dressings as a thickener.

F. One kind of algae is used to make agar-agar, which forms a jellylike material good for growing bacteria in hospitals and laboratories.

G. Algae may eventually be used in space flights.

1. Because algae carry on photosynthesis, they are able to use the carbon dioxide that the passengers give off, and produce fresh oxygen.
2. Because they grow so rapidly, there can always be a fresh supply on hand, to be strained out, dried, and then prepared for use as flour in baking or for use in soups.

BACTERIA

I. What Bacteria Are

A. Bacteria are tiny plants that have no roots, stems, and leaves.

B. They do not have any chlorophyll, so they cannot make their own food.

1. Bacteria that get their food from living plants or animals are called **parasites**.
2. Bacteria that get their food from dead plants and animals, or from materials made from plants and animals, such as food products, are called **saprophytes**.

C. Because bacteria do not have chlorophyll, they were once thought to be animals.

D. They are usually colorless, but some are brightly colored.

E. Bacteria are members of the large group, or **phylum**, of plants called **Thallophytes**.

F. Biologists divide the Thallophytes into two smaller groups, or **subphyla**, called **algae** and **fungi**.
   1. Algae have chlorophyll and can make their own food by photosynthesis.
   2. Fungi do not have chlorophyll and cannot make their own food.

G. For a long time biologists classified bacteria as a member of the fungi group, but now many biologists prefer to separate the bacteria from the other fungi and place them in their own phylum.

H. Other members of the fungi group include molds, mildews, rusts, smuts, yeasts, and mushrooms.

II. Structure and Kinds of Bacteria

A. All bacteria are made up of just one cell.

B. They are so tiny that it is hard to see them even with a powerful microscope.
   1. Their size ranges from 1/10,000 to 1/100,000 inch in width.
   2. They are so small that hundreds of thousands of them can be placed on the period at the end of this sentence.

C. All bacteria have a thin cell wall surrounding the cell.

D. Biologists classify bacteria into three main groups, according to their shapes.
   1. The round, ball-shaped forms of bacteria are called **cocci**.
   2. The rod-shaped forms of bacteria are called **bacilli**.
   3. The curved, twisted, spiral-shaped forms of bacteria are called **spirilla**.

E. Many cocci and bacilli live together in groups, called colonies.
   1. Some cocci live in pairs, and the two cocci are always together.
   2. Some cocci colonies are in clumps, but other colonies form chains that look like a string of beads under the microscope.
   3. The most common grouping of bacilli colonies is also in chains.

F. Many bacilli and spirilla have tiny, thread-like hairs, called **flagella**, growing out of their cells.
   1. Some have these hairs only at one or both ends of the cell, but others have these hairs all around the cell.
   2. These hairs have a whiplike movement, which makes it possible for the bacteria to move about in water, blood, and other liquids.
   3. Because these bacteria can move, they were thought at one time to be tiny animals.

III. Where Bacteria Are Found

A. Bacteria can be found everywhere.

B. They are in the air.

C. They are in the waters of streams, ponds, lakes, and oceans.

D. They are found in ice on the surface of ponds and lakes.

E. They are in the soil.

F. They are found in living things (plants, animals, and man).

G. They can be found in dead plants and animals, and in garbage.

IV. What Bacteria Need to Grow

A. Bacteria need a suitable temperature for growth.
   1. This suitable temperature varies for different bacteria.
   2. Some bacteria grow well in high temperatures, and others grow well in low temperatures.
   3. Most bacteria grow best at temperatures ranging from 80 to 100 degrees Fahrenheit.
   4. Very high temperatures kill most bacteria.
   5. Cold temperatures do not usually kill bacteria, but they either stop or slow down their activity and growth.

B. Bacteria need water or moisture for growth.
   1. Lack of water does not kill most bacteria, but it does stop or slow down their activity and growth.
   2. This is the reason why dehydrated foods

can be stored for long periods of time without spoiling.

C. Bacteria need darkness for growth.
   1. Sunlight slows down the growth of bacteria.
   2. The ultraviolet rays of the sun and of ultraviolet lamps can kill bacteria.

D. Bacteria need a suitable food supply for growth.
   1. Parasitic bacteria get their food from living plants and animals.
   2. Saprophytic bacteria get their food from dead plants and animals, or from materials made from plants and animals, such as food products.
   3. Most bacteria can live on a wide variety of food materials.
   4. Some bacteria can live only on special food materials.
   5. Pneumonia bacteria prefer only lung tissue, and typhoid bacteria prefer intestine tissues.

E. Some bacteria, called **aerobic bacteria,** must have free oxygen from the air to live, and will die in the absence of air.

F. Some bacteria, called **anaerobic bacteria,** cannot live in free oxygen.
   1. They get their oxygen by breaking down chemicals in foods containing oxygen.
   2. Anaerobic bacteria in tightly sealed cans of food are responsible for food poisoning, which is called **botulism.**
   3. **Tetanus,** or lockjaw, is produced by anaerobic bacteria that live in the soil or on objects and become active in deep cuts or punctures where the air cannot reach them.

V. How Bacteria Reproduce

A. Bacteria reproduce by **fission,** in which the cell divides to form two new cells.
   1. The cell separates into two cells simply by forming a wall through its middle.
   2. In some cases the two new cells break apart, and in other cases they stay connected to form a colony.

B. When conditions for growth are just right, the new cells can reach full size in 20 to 30 minutes and be ready to split in two again.
   1. This ability to grow and reproduce quickly is what makes bacteria so important and dangerous.
   2. When conditions are right, a few hundred bacteria can become millions in a very short time.

C. When conditions are unfavorable for growth, bacteria protect themselves by having each cell shrink into a small round body, called a **spore.**
   1. These spores develop thick protective covers or walls, which help the spores live through extreme conditions of cold, heat, dryness, and lack of food.
   2. The spores can be carried in all directions for long distances by the wind and other means.
   3. When bacteria are spores, they remain quiet and do not grow or reproduce.
   4. But, when conditions are favorable again, the spores become bacteria cells once more, grow quickly, and then reproduce by fission.
   5. Spore formation is especially common with bacilli, the rod-shaped bacteria.

VI. Helpful and Harmful Bacteria

A. Most bacteria are harmless, and live in the air, soil, water, and even in our bodies without seeming to do any harm.

B. Many bacteria are quite helpful to man in many ways.
   1. One group of bacteria sours milk, which is important in the making of butter and cheese.
   2. Certain kinds of cheeses, such as Swiss cheese, get their flavor from the action of bacteria.
   3. One group of bacteria changes alcohol into vinegar.
   4. The action of bacteria on the stems of the flax plant loosens the plant fibers, which are then stripped and woven into linen.

5. Bacteria are used in curing tobacco, giving the tobacco a special flavor.
6. Bacteria help separate the flesh from animal skins and, in a process called tanning, change the skin into soft leather.
7. Bacteria are used in septic tanks to get rid of sewage, by changing the solid wastes into easily removable liquids.
8. Bacteria act quickly on dead plant and animal matter, changing it into **humus,** which enriches the soil.

C. Certain bacteria, called **nitrogen-fixing bacteria,** take nitrogen gas from the air and change it into nitrogen materials that plants need to grow.

1. Although plants need nitrogen, they cannot use the free nitrogen in the air.
2. The nitrogen-fixing bacteria in the soil gather and form little knobs on the roots of leguminous plants, such as beans, peas, and clover.
3. These bacteria then take the free nitrogen from the air and change it into the kind of nitrogen materials that the plant can use.
4. When the plants die, they leave the soil richer in nitrogen materials, which can be used by other plants.

D. Some bacteria are harmful to man.

1. Some bacteria make food spoil, producing poisonous materials, called **toxins,** which can cause illness and even death.
2. Some bacteria cause disease, such as pneumonia, typhoid fever, tuberculosis, and scarlet fever.

VII. How Harmful Bacteria May Be Controlled

A. Ultraviolet rays can kill bacteria.

B. Certain chemicals, called **disinfectants** or **germicides,** can kill bacteria.

C. Heat kills many bacteria.

1. Harmful bacteria in raw milk are killed by heating the milk to 140 degrees Fahrenheit for 20 to 30 minutes.
2. Milk treated this way is said to be **pasteurized.**
3. When food is canned, it is first heated to kill any harmful bacteria in the food, and then sealed in airtight containers to prevent any other harmful bacteria from getting into the containers.

D. When it is difficult or inconvenient to kill bacteria, they can be controlled by stopping them from growing.

1. Certain chemicals, called **antiseptics,** can stop bacteria from growing.
2. Cold temperatures and quick-freezing can slow down or stop the growth of bacteria.
3. The removal of water, called **dehydration,** from foods stops bacteria from growing.
4. Salting, sugar curing, and pickling all preserve foods because both the salt and sugar remove moisture from the bacteria cells and stop them from growing.
5. Smoking foods also removes moisture from bacteria cells and stops their growth.

THE FUNGUS FAMILY

I. What Fungi Are

A. Fungi are members of a large group, or **phylum,** of plants called **Thallophytes.**

B. Thallophytes are very simple plants, having no roots, stems, and leaves.

C. Biologists divide the Thallophytes into two smaller groups, or **subphyla,** called **algae** and **fungi.**

1. Algae have chlorophyll, so they are able to make their own food by photosynthesis.
2. Fungi do not have chlorophyll and cannot make their own food.

3. Most algae live in the water, and most fungi live on land.

D. Common members of the fungus group include molds, mildews, yeasts, rusts, smuts, and mushrooms.

E. For a long time bacteria were classified as a member of the fungus group, but, because of their unusual characteristics, many biologists now prefer to place bacteria in their own phylum.

II. General Characteristics of Fungi

A. There are almost 100,000 different kinds of fungi.

B. Fungi vary in size, some being so tiny that they can only be seen under the microscope, and others combining to form the large masses that make up mushrooms and puffballs.

C. Most fungi are made up of threads or filaments, called **hyphae.**

1. Each hypha is made up of many cells, some with cell walls and some without cell walls.
2. The whole mass of hyphae that make up the fungus is called the **mycelium.**
3. The hyphae themselves are white or gray, but many fungi have red, orange, yellow, green, blue, or black pigments that give the fungi a special color.

D. Fungi grow best in darkness when there is moisture present and when the temperature is warm.

E. Since fungi have no chlorophyll, they must get their food from other sources.

1. Some fungi are **parasites,** getting their food from living plants and animals.
2. Other fungi are **saprophytes,** getting their food from dead plants and animals, or from materials made from plants and animals, such as food products.

F. Nearly all fungi are **aerobic,** being able to use the free oxygen in the air to live.

G. All fungi can reproduce by forming tiny round bodies, called spores.

1. The fungi produce tremendous numbers of spores.
2. These spores have a protective cover or wall around them.
3. The spores are carried off in all directions by the wind and other means.
4. They float through the air and land on objects.
5. If conditions are favorable for growth (moisture, warm temperature, darkness, suitable food supply), the spores become fungi.
6. When conditions are unfavorable, the spores can live quietly without growing for long periods of time until conditions become favorable for growth again.

H. Some fungi can reproduce by forming sexual cells, called **gametes.**

1. The male cell is called a sperm, and the female cell is called an egg.
2. The male and female cell unite to form a mass, called a **zygote.**
3. The zygotes form new fungi, which can then reproduce either by forming spores or by forming gametes and zygotes.

III. Molds

A. The word **mold** is a common name for many different kinds of fungi.

B. Molds grow best in places that are dark and damp.

C. Although most molds grow best in warm temperatures, some grow well at temperatures near freezing.

D. Molds can grow on most foods, and also on paper, leather, and wood.

E. Most molds are made up of the threads or filaments, called **hyphae.**

F. Some molds, such as bread mold, have three kinds of hyphae.

1. Tiny, rootlike hyphae, called **rhizoids,** grow downward into the bread, digest the food materials in the bread, and then take in, or absorb, the digested food materials.
2. Other hyphae, called **stolons,** spread out horizontally over the surface of the bread, and then grow downward to form more rhizoids.

3. Some hyphae grow upright, and their purpose is to form spores.
4. After a few days, round bodies or knobs appear on the ends of these upright hyphae.
5. Each knob is a spore case, called a sporangium, with thousands of spores in it.
6. These spores are colored, and give the molds their characteristic color.
7. When the spore cases (sporangia) are ripe, they split open and the spores float away in the air.
8. Each spore can form a new hypha, which will soon become a complete mold made up of many hyphae.

G. All molds reproduce by forming spores, but some can also reproduce by forming sexual cells (gametes).

1. Sometimes two hyphae of the same mold plant develop connecting branches, which join together.
2. Where the branches join together, a cell from each branch acts as a sexual cell, and these cells unite to form a zygote.
3. The zygote then begins to form a new mold plant.

H. Some molds are parasitic, and others are saprophytic.

I. Molds may be harmful.

1. Many molds spoil foods.
2. Molds growing on fruit trees damage the fruit.
3. Some parasitic water molds kill fish and other sea animals.

J. Molds can be helpful.

1. Molds are used in making such cheeses as roquefort, camembert, and limburger.
2. The antibiotics, such as penicillin, streptomycin, and aureomycin, are obtained from molds.

IV. Mildews

A. Mildews are fungi that are closely related to molds.

B. Most mildews are parasites.

C. Some mildews are downy, and attack such plants as radishes, potatoes, cereal grains, sugar cane, and tobacco.

D. Some mildews are powdery, and attack such plants as lilacs, roses, phlox, clover, grapes, and apples.

E. Mildews are either whitish or dark colored.

F. Black mildew is often found on clothes exposed to dampness for a long time.

G. Mildews reproduce by spores.

V. Yeasts

A. Yeasts are tiny, one-celled fungi, usually oval in shape.

B. They usually reproduce in a special way, called **budding.**

1. When conditions are favorable, a little knob or bud pushes out from one side of the yeast cell.
2. This bud grows quickly and later breaks away to form a new yeast cell.
3. Sometimes many buds stay attached to the same yeast cell and form a chain.

C. When conditions are unfavorable, a yeast cell may produce a spore case, usually with four spores in the case.

D. Yeast is important to man because of its action on sugar.

1. It breaks down sugar to alcohol and carbon dioxide gas.
2. This action is called **fermentation.**

E. Yeast is used in making bread.

1. Bubbles of carbon dioxide gas are formed, which swell and make the dough rise.
2. This bubbling leaves many small spaces in the bread, and makes the bread light and fluffy.
3. As the bread is baked, the heat drives off the carbon dioxide and the alcohol that have been formed.

F. When making alcohol by using yeast, the carbon dioxide is allowed to escape and the alcohol is saved.

G. Fruits, such as grapes and apples, ferment when they are crushed.

1. Their skins usually have wild yeasts on them.

2. When the skin of these fruits is broken, the yeasts act on the sugar in the fruit, and turn the juice into wine and cider.

H. Yeasts are also helpful to man because they produce vitamin B_2 in their cells.

VI. Rusts and Smuts

A. Rusts and smuts are parasitic fungi.

B. Rusts produce reddish-brown spores that look like rust, and destroy such plants as wheat, apple trees, white pine trees, roses, oranges, and melons.

C. Smuts produce blackish spores, and destroy cereal grains, such as corn, oats, barley, and wheat.

VII. Mushrooms

A. Mushrooms are the largest fungi.

B. They are saprophytes, living on dead plant and animal matter in the soil.

C. They may grow underground for years, producing a large mass of tangled threads (hyphae), which eventually come together just below the surface of the ground to form a small cap.

D. When the weather is damp, especially in the spring or the fall, this closely packed mass pushes its way above the ground and the cap opens to form a mushroom.
   1. The stalk of the mushroom is called the **stipe.**
   2. The umbrella-shaped top of the mushroom is called the **cap** or **pileus.**
   3. On the underside of the cap are fleshy plates, called **gills,** which contain the spores of the mushroom.

E. Some mushrooms have a ring around their stalk (stipe) that is the point where the cap was attached to the stalk before the mushroom moved above the ground and the cap spread open.

F. Each fleshy gill contains hundreds of spore cases.
   1. Each spore case contains four spores.
   2. The spores may be colored black, white, pink, yellow, or brown.

G. Some mushrooms are good to eat, but others may be very poisonous.

H. Puffballs are like mushrooms, except that they are not umbrella-shaped.
   1. They are either round or pear-shaped balls, usually white in color.
   2. When the puffballs are fully grown, they dry up and split open, sending all their spores out into the air.
   3. Puffballs can be as large as 2 feet across when fully grown.
   4. They can be eaten when they are young and before their spores have ripened.

VIII. Lichens

A. A lichen is a plant usually grouped with the fungus family.

B. Actually, a lichen is a plant that is made up of an alga and a fungus that are living together.
   1. The alga and the fungus both help each other.
   2. The fungus gets its food from the alga, which has chlorophyll and makes food by photosynthesis.
   3. In return, the fungus protects the alga with its hyphae (threads), and supplies the alga with the moisture it needs for photosynthesis.
   4. This arrangement, where two living things live together and help each other, is called **symbiosis.**

C. Lichens are usually green because of the green algae in them, but some lichens have other pigments as well, which make the lichens appear red, orange, yellow, or brown.

D. Lichens grow on the bark of trees and on the ground.

E. Lichens growing on rocks make the rock crumble and turn into soil.
   1. The lichen gives off carbon dioxide gas, which combines with water to form carbonic acid.
   2. The acid causes the rock to become soft and crumbly, changing it eventually into soil.

F. Lichens can grow anywhere, some even growing in desert regions and others near the north and south poles.

G. One kind of lichen is used by reindeer as food.

H. Lichens have been used in making dyes, in tanning hides for leather, and in making perfumes. Litmus paper, used to test acidity, is made with a lichen dye. In China, Japan, and Iceland, people eat lichens.

MOSSES AND LIVERWORTS

I. What Mosses and Liverworts Are

A. Mosses and liverworts are members of a group, or **phylum**, of plants called **Bryophytes.**

B. They are found all over the world.
   1. They are found on plains and on mountains.
   2. They are found in the tropics and in the polar regions.

C. Most of them live on land, but a few live in water.

D. They are all rather small plants.

E. They have chlorophyll, are colored green, and can make their own food.

F. They are very simple plants.
   1. They have simple leaves, but no true roots and stems.
   2. However, they do have rootlike and stemlike parts.

II. Mosses

A. Moss plants are small and tend to grow crowded together.

B. They tend to form a thick velvety carpet on moist ground under trees in the deep woods, on damp creek banks, on decaying logs, and on wet rocks.

C. They have a very simple structure.
   1. Each moss plant has tiny leaves and a slender stalk, but these leaves and stalks do not have tubes that conduct water and food, as real stems and leaves do.
   2. The moss plant has no roots, but instead it has hairlike threads, called **rhizoids.**
   3. These rhizoids anchor the plant to the ground and absorb moisture and dissolved minerals from the soil for the plant to use.

D. The moss plant has a very interesting method of reproduction.
   1. Male reproductive organs form on some plants, and female reproductive organs form on other plants.
   2. In some kinds of moss plants, both the male and female reproductive organs are formed on the same plant.
   3. The male organ is club-shaped and has sexual cells (gametes), called **sperm,** in it.
   4. The female organ is shaped like a narrow-neck bottle and has a single sexual cell (gamete), called an **egg,** in its swollen base.
   5. When the male organ is fully grown, it opens and allows the sperm to escape.
   6. The sperm cells have two threads, called **cilia,** at one end, and use these cilia to swim to the female organ after a rain or when the moss plant is covered with dew.
   7. A sperm cell enters the female organ and unites with the egg to form a fertilized egg, called a **zygote.**
   8. The zygote (fertilized egg) stays in the female organ and begins to grow, producing a long, thin stalk that rises above the top of the plant.
   9. The top of the stalk then swells and becomes a spore case, which is covered by a little hood.
   10. There are many tiny spores in the spore case.

11. When the spores become ripe, the hood falls off and the spore case bursts open, allowing the spores to escape.
12. The spores are carried away by the wind and eventually fall to the ground.
13. If conditions are right, the spore produces a mass of threads, which sends up leafy buds that develop into tiny moss plants.
14. These moss plants grow, develop sex organs, and start the whole process of reproduction all over again.
15. Moss plants thus go through a reproductive cycle in which there is a spore stage followed by a sexual stage, which forms a spore stage again.

E. Mosses are important because they help make soil.

1. Their rootlike parts (rhizoids) grow in cracks of rocks and make the rock crumble.
2. These rootlike parts also give off acids, which break up the rock and form more soil.

F. One kind of moss, called **sphagnum** or **peat moss**, is widely used by man.

1. It grows in small lakes and ponds, forming floating masses.
2. These masses become bigger and thicker each year, and eventually cover all the water and form a bog.
3. This bog may thicken, as grass, shrubs, and small trees grow in it, so that the bog becomes solid land over a long period of time.
4. Dried peat moss is used as a packing material for dishes, glassware, and plants that are to be shipped to different parts of the country.
5. The gardener works peat moss into the soil because it helps loosen thickly packed soil and because it holds water in the soil during the dry summer months.

III. Liverworts

A. Liverworts are small plants that grow in wet places, such as along the banks of a stream.

B. They look like thin, ribbonlike leaves that grow flat along the ground; they are attached to the ground with rhizoids.

C. Like mosses, liverworts also go through a reproductive cycle, having both a spore stage and a sexual stage.

FERNS

I. What Ferns Are

A. Ferns are members of a group, or **phylum**, of plants called **Pteridophytes.**

B. Other members of this group (phylum) are the horsetail rushes and the club mosses.

C. They all have true roots, stems, and leaves, but they do not produce flowers, fruits, and seeds.

D. They are mostly land plants, and grow best in cool, damp, shaded places where the soil is rich.

E. Some grow in the cracks of rocks and cliffs, and others grow in fields and open woods.

F. They range in size from small mosslike plants to plants the size of a good-sized tree.

G. They all have chlorophyll, are colored green, and make their own food.

II. Ferns

A. Ferns were very numerous millions of years ago, forming large forests in the wet and marshy land that was common at that time.

1. Giant ferns as large as trees were quite common.
2. Smaller ferns, much like those found today, also lived during that period.

B. Today tree ferns are found only in the tropics, where they can be as much as 50 feet tall with leaves 12 to 14 feet long.

C. Ferns are much smaller in the temperate zones.

D. The stems of these small ferns are underground, growing horizontally just below the surface.
1. Such underground stems are called rhizomes.
2. Each year these stems put up new leaves.
3. Fine roots also grow from these stems.

E. Fern leaves are usually called **fronds**, and in most ferns these are the only parts of the plant that appear above the ground.
1. They are **compound leaves** because they have many tiny leaflets arranged along one main vein, called the **midrib.**
2. The veins of fern leaves are forked, and this forking is a characteristic of ferns.
3. When the leaves appear in the spring, they are rolled up tight and they are covered with a hairy growth at their base.
4. When the leaves unroll, they lose this hairy covering.

F. Ferns go through a reproductive cycle, having both a spore stage and a sexual stage.
1. When the fern leaves are fully grown, spore cases form on their underside.
2. There are many tiny spores in each spore case.
3. When the spores become ripe, the spore case bursts open, and the spores are carried away by the wind.
4. When a spore falls on a moist place where conditions are right for growth, the spore forms a threadlike chain or filament of cells.
5. This chain or filament thickens and then broadens at the tip, which becomes a flat, heart-shaped green body, called a **prothallus,** that is notched on its upper side.
6. The prothallus has hairlike threads, called **rhizoids,** on its underside.
7. The rhizoids hold the prothallus to the ground and absorb moisture from the soil.
8. Male sexual organs, each containing several **sperm** cells, develop among the rhizoids.
9. Female sexual organs, each containing one **egg** cell, develop on the underside of the prothallus near the notch.
10. When the male organ is fully grown, it opens up and allows the sperm cells to escape.
11. The sperm cells swim to the female organs after a rain or when the plant is covered with dew.
12. A sperm cell enters a female organ and unites with the egg to form a fertilized egg, called a zygote.
13. The zygote then grows into a fern plant, as we know it, with roots, stem, and leaves.

G. The leaves of some ferns form tiny buds, which break off and form new ferns.

H. Some ferns can form new ferns from their leaves, if the leaves bend down and touch the ground.
1. When the tip of the leaf touches the ground, roots form at the tip.
2. These roots then develop stems and leaves to become a new fern plant.
3. The tip of the leaf dies, which separates the new plant from the parent plant.

I. Many ferns are used to make Christmas wreaths.

J. The coal that we use today comes from the ferns that lived and died millions of years ago.
1. Large masses of dead ferns accumulated in layers in the swampy areas where they grew.
2. These layers turned into coal under the influence of great heat and pressure that were produced by strong upheavals and movements of the earth's crust.

III. Horsetail Rushes and Club Mosses

A. Horsetail rushes and club mosses are closely related to the ferns.
B. They are like the ferns in structure and in the way they reproduce to form new plants.
C. Like the ferns, they were very numerous millions of years ago.
   1. At that time they were the size of trees.
   2. Most of them are now extinct, and their remains can be seen as leaf and stem imprints.
   3. Those that live today are small plants.
D. There is only one living group of horsetail rushes today, but they can be found everywhere.
   1. They are usually found in wet places, but a few kinds do grow in dry places.
   2. They have thin, dark green, rodlike stems, with light-colored cones at their tips.
   3. The leaves in these cones are small and look like scales.
   4. Most of the photosynthesis takes place in the stem.
E. Club mosses look more like mosses than ferns.
   1. They grow on the ground in temperate regions and on tree trunks in tropical regions.
   2. They grow best in damp places.
   3. They have slender stems and scalelike leaves.
   4. They grow clublike stalks on some of their branches.
   5. Some club mosses are dainty and beautiful, and are very commonly used in making up bouquets, corsages, and Christmas wreaths.

LEARNING ACTIVITIES FOR SECTION TWO: "PLANTS WITHOUT SEEDS"

ALGAE

1. *Collect and examine algae* · Algae are easiest to collect during the spring and summer. They may be found as a greenish scum in shallow or stagnant pools and lakes, and also as a greenish coating on moist stones or on the damp bark of the shaded side of a tree. Collect the algae from pools and lakes in large wide-mouthed jars, taking along a good amount of the water in which the algae were found. Do not put too many algae in one jar. Collect algae from bark by prying off a few small pieces of the bark and soaking the bark in tap water that has been allowed to stand for 24 hours in a large, wide-mouthed, open jar (to allow any chlorine in the water to escape). Algae from stones may be scraped off and placed in jars containing tap water that also has been allowed to stand for 24 hours.

Because the algae kept in containers die rather quickly, they should be examined as soon as possible. Keep the containers in strong light, but not in direct sunlight. Place a drop of the green material on a microscope slide, cover with a cover glass, and examine the algae under both the low and high powers of a microscope. Note the tiny bodies containing chlorophyll. See if you can find examples of algae in different stages of reproduction. Find pictures of the common algae and use these to try to identify the specimens you have collected.

2. *Conditions for growth of algae* · Place samples of algae in complete darkness, medium to strong light, and in direct sunlight. Also, keep samples of algae in the refrigerator, on or near a heated radiator, and at room

temperature. This variation of conditions will help the children learn the optimum conditions of light and heat for the growth of algae.

3. *Examine seaweed or kelp* · Look for rockweed, seaweed, or kelp along the seashore. If you live inland, obtain some from the fish store. Ask for the kind of seaweed or kelp that is used to pack lobsters, clams, or oysters that are flown or shipped from the seacoast to your city or town. Examine and cut open the air bladders. Look for and examine the cup-like holdfast. The larger specimens will have divisions that look like stems and leaves.

Have the pupils read about and report on the Sargasso Sea and the sargassum floating in it.

BACTERIA

1. *Collect or grow bacteria* · Boil a pint of water and add 4 tablespoons of nutrient agar. If nutrient agar is unavailable, use 4 tablespoons of gelatin, one bouillon cube, a tiny pinch of salt, and a tiny pinch of baking soda. Boil the mixture for about 15 minutes. Let the culture liquid cool a few minutes until it is quite warm, but not hot. An alternate and much simpler culture material may be prepared by boiling a potato in water to which a pinch of baking soda has been added. Slices of the boiled potato will also grow bacteria, but not as well as the nutrient solutions.

Obtain four or five Petri dishes that have been sterilized in an oven for 1 hour at 225 to 250 degrees Fahrenheit. If Petri dishes are unavailable, use identical saucers instead. Place one saucer on top of another and hold the saucers in place by taping their edges at two or three places (Figure 13–12). Stack four or five pairs of saucers in the oven and heat as directed. After 1 hour, remove the Petri dishes or saucers and allow them to cool to room temperature, keeping them covered at all times. These containers will be used to hold the nutrient solution for collecting and growing bacteria.

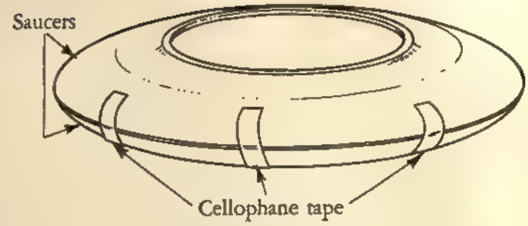


FIGURE 13–12.
A HOMEMADE PETRI DISH.

Pour about ¼ inch of nutrient agar or gelatin mixture into each culture dish and cover the dishes again. If a boiled potato is used as a culture material, cut off thin slices with a sterilized knife and transfer them to the culture dishes with sterilized forceps or tweezers.

Collect and grow bacteria in several different ways. Expose the culture material by lifting the top of a culture dish quickly, and then have a child cough over the culture materials. Another child can stroke a dirty finger across the culture material or drop some dirt that has collected under his fingernails. Expose the culture material to the air in the classroom or street for about 15 minutes. Keep one dish sterile and closed at all times so that it will serve as a control. Keep the dishes in a warm, dark place. In a few days different colored spots will appear in the exposed dishes, showing the presence of colonies of bacteria.

2. *Examine bacteria under a microscope* · Make a transfer needle by pushing the sharp point of a needle well into a small cork stopper. Use the cork stopper as a handle and sterilize the eye of the needle in a flame. Use the eye of the needle to transfer the bacteria to a microscope slide. Add a coloring agent, such as methylene blue or eosin, which can be obtained from the drugstore. The coloring agent should be very dilute, and the proper dilution can be prepared for you by the pharmacist. Although bacteria are very small, some of the larger ones can be seen by focusing the microscope very carefully and by experimenting with the angle and amount of light enter-

ing the microscope. Look for examples of the three different kinds of bacteria, and draw diagrams of them on the chalkboard.

If the variety of bacteria is limited, try growing others by placing a handful of dead or decaying grass and leaves in a large, wide-mouthed jar of water. First expose the jar to the air for 1 or 2 days, and then cover the jar and let it stand for a few days more. The water should now have a good supply of bacteria. Place a drop of the water on a microscope slide, and a drop of the coloring agent described above, cover with a cover glass, blot up the excess liquid around the edges of the cover glass with the tip of a blotter, and examine the bacteria under the high power of a microscope.

3. *Conditions for the growth of bacteria* · Prepare six sterile culture dishes containing nutrient culture material, as described in Learning Activity 1 above. Grow bacteria in each dish by touching a sterile needle, prepared as described in Learning Activity 2 above, to a bacteria colony growing in another dish, and by smearing the bacteria on the needle across the culture material in the dishes.

Place one dish in a dark, warm place and another in the refrigerator, where it is dark and cold, and examine the dishes after a few days. Repeat the experiment, using a dark, warm place and a bright, sunny, warm place. Repeat the experiment, using a dark, warm, moist place and a dark, warm, dry place. Create a dark, warm, dry place by placing the dish on a radiator or a hot plate set at low heat, and then covering the dish with a tin can over it. The experiments will show that bacteria grow best under dark, warm, moist conditions.

4. *Reproduction of bacteria* · Draw diagrams showing how bacteria reproduce. By assuming that reproduction takes place every 30 minutes, and that all the bacteria also live and reproduce, have the children calculate how many bacteria will be formed in 24 hours, starting with just one of the bacteria.

5. *Helpful and harmful bacteria* · Have the children read about and report on the different ways that bacteria can be helpful and harmful to man.

6. *Controlling harmful bacteria* · Prepare and inoculate five sterile culture dishes containing nutrient culture, as described in Learning Activity 3 above. Place one dish in direct sunlight, and a second dish in the oven, where it is both hot and dry. To the third dish add some disinfectant, such as Lysol or Cresol. To the fourth dish add some antiseptic, such as tincture of iodine or Metaphen. To the fifth dish add an antibiotic, such as a tablet or capsule of penicillin, which has been dissolved or mixed in water. The antibiotic can be obtained from the drugstore or a doctor. Note that bacteria colonies fail to grow in each dish.

Have the children read about the work of such men as Pasteur, Koch, and Lister in controlling harmful bacteria.

THE FUNGUS FAMILY

1. *Collect or grow molds* · Rub a piece of bread across a dusty surface, and then moisten the bread. Place the bread in a closed container and place it in a warm, dark place. After a few days a white, cottonlike mold will form. Then black spots, which are spore cases, will also appear. Molds can also be formed by placing cheese, jam, or a wet orange in a closed container and keeping the container in a warm, dark place for several days.

New or more of the same items can now be inoculated if some of the mold is transferred to the items. An orange or apple can be inoculated simply by picking up some mold from one fruit with a sterilized pin or needle, plunging the mold into a fresh fruit, and then keeping the fruit in a warm, moist place.

2. *Examine molds* · A magnifying glass will show the threads and black spore cases of molds quite clearly. To see the spores themselves, place a bit of the mold on a microscope slide, and then add a drop of water and a

drop of coloring agent, such as methylene blue, prepared and properly diluted by a pharmacist. Cover with a cover glass and examine under the high power of a microscope. Move the slide until a spore case can be clearly seen, and then examine the spores inside.

3. *Conditions for growth and control of molds* · Have the children try growing molds, as described in Learning Activity 1 above, under moist and dry, warm and cold, and light and dark conditions. Then have the children draw conclusions as to what are the most favorable conditions for growing and for controlling molds.

4. *Look for and examine mildew* · Mildew will often form when old shoes, pieces of leather, or books are placed in a dark, moist, warm place. This mildew is usually colored black. A white mildew will often form on the leaves of flowering plants when the air is hot and humid, and the weather has been rainy. Examine the mildew both under a magnifying glass and a microscope, as described in Learning Activity 2 above.

5. *Grow and examine yeast cells* · Dissolve 1 teaspoon of sugar in a tumbler of warm (not hot) water. Add a quarter of a yeast cake or a package of dried yeast, and let the tumbler stand for 24 hours in a warm place. Place a drop of the yeast culture, which is formed, on a microscope slide, cover with a cover glass, and observe the yeast plants under both the low and high power of a microscope. Look for cell shapes, special features of yeast cells, and evidence of budding.

6. *The action of yeast on dough* · Mix flour, water, and sugar together in the proper proportions to make bread dough. Divide the dough into two equal parts, and mix one part with half a yeast cake or package of dry yeast that has been stirred in some water. Place each dough sample in a pan and set in a warm place for a few hours. The dough with the yeast will rise as the action of the yeast produces bubbles of carbon dioxide that expand in the dough.

7. *The effect of temperature on the action of yeast* · Prepare a batch of bread dough and yeast, as described in Learning Activity 6 above. Divide the dough into three equal parts and place each part in a pan. Put one pan in the refrigerator, another sample in a warm place, and the third sample in a hot place. Examine all three batches of dough after a few hours. The dough in the warm place will show the best action of the yeast.

8. *Yeast causes fermentation* · Dissolve a heaping tablespoon of sugar in a tumbler of warm (not hot) water. Add a quarter of a yeast cake or package of dried yeast, and let the tumbler stand for several days in a warm place. Smell the yeast culture, and note the odor of ethyl alcohol. Point out that the yeast causes the sugar solution to ferment, producing ethyl alcohol and carbon dioxide.

9. *Fermentation produces carbon dioxide* · Prepare a yeast and sugar solution, as described in Learning Activity 8 above. Pour this solution into a test tube or narrow-necked glass jar fitted tightly with a one-hole rubber stopper. Insert a small piece of glass or plastic tubing into the hole of the stopper and connect this glass tube to another glass tube with rubber tubing (Figure 13–13). Insert the second glass tube into a test tube or glass jar containing a solution of clear limewater, which may be obtained from the drugstore. Place the apparatus in a warm place. In a few hours the limewater will turn milky, showing the presence of carbon dioxide. You can show that limewater is a test for carbon dioxide gas by bubbling your breath through a soda straw into a test tube containing a little limewater.

10. *Rusts and smuts* · If rusts and smuts are available, examine them under the microscope and look for special features. Have the children read about wheat rust, apple rust, white-pine blister rust, chestnut blight, Dutch elm disease,

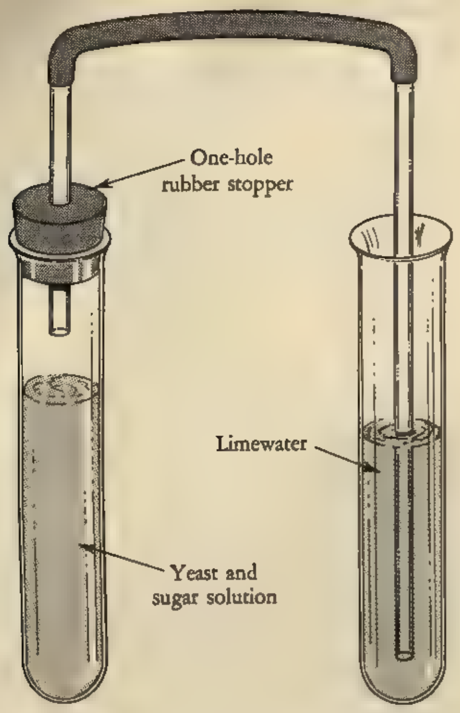


FIGURE 13–13.
WHEN YEAST FERMENTS, THE CARBON DIOXIDE IT GIVES OFF CAUSES LIMEWATER TO BECOME MILKY.

and corn smut. In each case they might like to tell the type of fungus that causes the disease, the plants that are affected, and how the diseases are spread.

11. *Examine mushrooms and make spore prints* · Collect full-grown mushrooms and examine the stalk, cap, and gills. Carefully and gently cut away the stalk of the mushroom. Coat a piece of smooth or shiny cardboard with egg white. If the gills of the mushroom are covered with light-colored spores, use dark cardboard. If the spores are dark, use light cardboard. Push three toothpicks vertically into the sides of the mushroom cap so that they will hold the cap suspended ⅛ inch above the cardboard (Figure 13–14). Place the cap on the cardboard and cover it with a wide-mouthed glass jar to prevent air currents from disturbing the spores. After 24 hours remove the jar carefully, and then remove the cap. The gills of the mushroom will be permanently outlined on the cardboard by the spores that have fallen upon it.

12. *Collect and examine puffballs* · Look for and examine puffballs that have not yet split open. Squeeze or crush the puffball over a piece of paper and observe the spores that drop on the paper. Examine the inside of the puffball.

13. *Collect and examine lichens* · Collect samples of lichens, which are found as gray-green patches on rocks and the bark of trees. Examine the lichens under a magnifying glass and a microscope. Note the network of gray fungus fibers that surrounds the green algae cells. Discuss the symbiotic arrangement whereby the fungus and algae live together and help each other.

Scrape a patch of lichen from a rock, and note the softer and more crumbly condition of the rock under the patch. The lichen gives

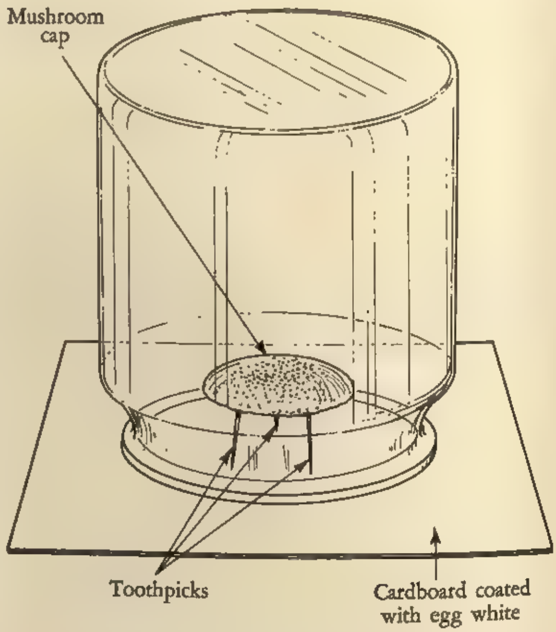


FIGURE 13–14.
OBTAINING SPORE PRINTS FROM MUSHROOMS.

off carbon dioxide gas, which combines with water to form carbonic acid. The acid causes the rock to crumble, and eventually turns the rock into soil.

MOSSES AND LIVERWORTS

1. *Collect and examine moss* · Mosses are easy to find in swampy areas and forests. However, they can also be found in cracks at the north side of buildings, in cracks of shaded sidewalks, on old paths, and on trees. Collect the mosses with a little of the soil in which they are growing and wrap them in damp newspaper. Cut out a few moss plants and place them in shallow water. Examine these plants with a magnifying glass and under the microscope. Note the tiny leaves, slender stalk, and hairlike rhizoids. Look for male and female reproductive organs, and for spore cases.

2. *Grow moss* · Place a mixture of rich soil and humus into a flower pot and water well. Shake some spore cases from growing moss on the soil, and place the pot in a place that has medium light. Cover the pot with a piece of glass to prevent the water in the soil from evaporating too quickly, and water as often as is necessary to keep the soil constantly moist. Mosses will grow in a few weeks. Draw diagrams to show the life cycle of the moss.

3. *Examine peat moss* · Obtain some dry peat moss and place it in a dish. Add water, and note how much water the peat moss will absorb. Feel how soft and spongy the wet peat moss is. Show how peat moss may cover a pond or small lake, converting it into a bog so that eventually the body of water becomes dry land.

4. *Collect and examine liverworts* · If you live near wooded areas where mosses and ferns can be found, you should be able to collect some liverworts. Be sure to collect them with a little of the same soil in which they are growing, and wrap them in damp newspaper. Examine the liverworts under the magnifying glass. Note the hairlike processes on the underside of the plant body. These processes attach the liverwort to the soil on which it grows.

FERNS

1. *Collect and examine ferns* · Make a collection of ferns that grow in your locality. They are usually found in shady places near streams and in moist, wooded areas. When collecting ferns, be sure to dig up their rhizomes and fine roots together with the soil in which they are growing. Wrap the ferns carefully in damp newspapers so that the soil is packed around the rhizomes and roots. Examine one of the ferns with a magnifying glass. Look for spore cases on the underside of mature fern fronds. If these spore cases cannot be seen with the magnifying glass, look for them under the low power of a microscope.

2. *Transplant ferns* · Place a layer of coarse gravel in a flower pot, and cover this layer with 1 inch of rich soil. Carefully place the rhizome and roots of the fern into the pot and, while holding the fern in one hand, slowly add a soil mixture made up of equal parts of rich soil, peat moss, and sand. Add this mixture until the rhizome is covered and the soil mixture is just as high around the fern as it was where the fern originally grew. Place the pot in a shallow pan of water, and keep in a place that has medium light. Do not water the soil on top of the pot, but keep water constantly in the pan instead.

3. *Grow ferns from spores* · Select a mature fern frond that has prominent spore cases on its underside, and place the frond on a piece of paper so that the spore cases touch the paper. Leave the frond on the paper for several days, and allow the spores to fall out on the paper. If the frond is tapped occasionally, this tapping will help the spores fall out of their cases.

Place a layer of coarse gravel in a flower pot, and then add a soil mixture made up of equal parts of rich soil, peat moss, and sand. Slowly pour boiling water over the soil in the pot to kill any molds or bacteria in the soil that might damage the growth of the fern plants. When the soil is cool again, sprinkle the spores from the paper onto the soil in the pot. Set the pot in a shallow pan of water, and cover the pot with a small pane of glass to keep the air above the spores warm and moist. In about 4 weeks tiny, heart-shaped green plants will sprout. If too many plants sprout, pull some out to relieve the crowded condition. In about 10 weeks these green plants will be mature and produce eggs and sperm. The sperm will fertilize the eggs, and in 4 to 6 months the fertilized eggs will grow into the plants we call ferns. Ferns and mosses are good plants for a terrarium (see Activity 14, p. 467).

BIBLIOGRAPHY FOR "PLANTS"

BLOUGH, GLENN O. *Plants Round the Year*. New York: Harper, 1959. 36 pp.

———. *Useful Plants and Animals*. New York: Harper, 1959. 36 pp.

BRUERE, MARTHA BENSLEY. *Your Forests*. Philadelphia: Lippincott, 1957. 163 pp.

BUCK, MARGARET WARING. *In Ponds and Streams*. Nashville, Tenn.: Abingdon, 1955. 72 pp.

CAVANNA, BETTY. *The First Book of Wild Flowers*. New York: Watts, 1961. 68 pp.

CORMACK, MARIBELLE B. *The First Book of Trees*. New York: Watts, 1951. 93 pp.

DE KRUIF, PAUL. *Microbe Hunters*. New York: Harcourt, 1932. 368 pp.

DICKINSON, ALICE. *The First Book of Plants*. New York: Watts, 1953. 71 pp.

DUDLEY, RUTH H. *Our American Trees*. New York: Crowell, 1956. 148 pp.

EGGLESTON, JOYCE SMITH. *About Things That Grow*. Chicago: Childrens, 1958. 30 pp.

FENTON, CARROLL LANE, and HERMINIE B. KITCHEN. *Fruits We Eat*. New York: Day, 1961. 128 pp.

———. *Plants That Feed Us: The Story of Grains and Vegetables*. New York: Day, 1956. 95 pp.

FENTON, CARROLL LANE, and DOROTHY C. PALLAS. *Trees and Their World*. New York: Day, 1957. 96 pp.

FERGUSON, GRACE F. *The How and Why Wonder Book of Wild Flowers*. New York: Grosset, 1962. 47 pp.

FOSTER, WILLENE K., and PEARL QUEREE. *Seeds Are Wonderful*. Chicago: Childrens, 1960. 32 pp.

GRANT, MADELEINE P. *Wonder World of Microbes*. New York: McGraw, 1956. 65 pp.

HUTCHINGS, ROSE. *Strange Plants and Their Ways*. Chicago: Rand McNally, 1958. 96 pp.

HUTCHINS, ROSS E. *This Is a Leaf*. New York: Dodd, 1962. 121 pp.

JAUSS, ANNE MARIE. *Our Friend the Forest, a Conservation Story*. New York: Doubleday, 1959. 61 pp.

JEWETT, FRANCES L., and CLARE L. MCCAUSLAND. *Plant Hunters*. Boston: Houghton, 1958. 230 pp.

JORDAN, HELENE J. *Seeds by Wind and Water*. New York: Crowell, 1962. Unpaged.

JUDGE, FRANCES. *Forest Fire*. New York: Knopf, 1960. 150 pp.

KAVALER, LUCY. *The Wonders of Algae*. New York: Day, 1961. 96 pp.

KIRKUS, VIRGINIA. *The First Book of Gardening*. New York: Watts, 1956. 69 pp.

KOHN, BERNICE. *Our Tiny Servants: Molds and Yeasts*. Englewood Cliffs, N.J.: Prentice-Hall, 1962. 62 pp.

LAUBER, PATRICIA. *Our Friend the Forest*. New York: Doubleday, 1959. 61 pp.

LEWIS, LUCIA Z. *The First Book of Microbes*. New York: Watts, 1955. 65 pp.

MINER, IRENE O. SEVREY. *The True Book of Plants We Know*. Chicago: Childrens, 1953. 47 pp.

PARKER, BERTHA M. *Adaptation to Environment*. New York: Harper, 1956. 36 pp.

———. *Dependent Plants*. New York: Harper, 1957. 36 pp.

———. *Flowers, Fruits, Seeds*. New York: Harper, 1958. 36 pp.

———. *Garden Indoors*. New York: Harper, 1957. 36 pp.

———. *The Garden and Its Friends*. New York: Harper, 1957. 36 pp.

———. *Leaves*. New York: Harper, 1959. 36 pp.

———. *Living Things*. New York: Harper, 1958. 36 pp.

———. *Plant and Animal Partnerships*. New York: Harper, 1958. 36 pp.

———. *Plant Factories*. New York: Harper, 1958. 36 pp.

———. *Seeds and Seed Travels*. New York: Harper, 1958. 36 pp.

———. *Trees*. New York: Harper, 1955. 36 pp.

PARKER, BERTHA M., and RALPH BUCHSBAUM. *Balance in Nature*. New York: Harper, 1958. 36 pp.

PARKER, BERTHA M., and ILLA PONDENDORF. *Domesticated Plants*. New York: Harper, 1953. 36 pp.

———. *The Plant World*. New York: Harper, 1957. 36 pp.

PLATT, RUTHERFORD. *1001 Questions Answered About Trees*. New York: Dodd, 1959. 318 pp.

PODENDORF, ILLA. *The True Book of Trees*. Chicago: Childrens, 1954. 47 pp.

RUSSELL, SOLVEIG PAULSON. *About Fruit*. Chicago: Melmont, 1962. 48 pp.

SCHATZ, ALBERT, and SARAH RIEDMAN. *The Story of Microbes*. New York: Harper, 1952. 172 pp.

SELSAM, MILLICENT E. *How to Grow House Plants*. New York: Morrow, 1960. 96 pp.

———. *Microbes at Work*. New York: Morrow, 1953. 95 pp.

———. *Plants That Heal*. New York: Morrow, 1959. 96 pp.

———. *The Plants We Eat*. New York: Morrow, 1956. 126 pp.

———. *Play with Leaves and Flowers*. New York: Morrow, 1952. 64 pp.

———. *Play with Plants*. New York: Morrow, 1949. 63 pp.

———. *Play with Seeds*. New York: Morrow, 1959. 93 pp.

———. *Play with Trees*. New York: Morrow, 1950. 64 pp.

SHANNON, TERRY. *The Wonderland of Plants.* Racine, Wis.: Whitman, 1960. 32 pp.

STEFFERUD, ALFRED. *The Wonders of Seeds.* New York: Harcourt, 1956. 119 pp.

STERLING, DOROTHY. *The Story of Mosses, Ferns, and Mushrooms.* New York: Doubleday, 1955. 159 pp.

WEBBER, IRMA E. *Bits That Grow Big.* Chicago: Scott, 1949. 64 pp.

———. *Thanks to Trees.* Chicago: Scott, 1952. 60 pp.

———. *Travelers All: The Story of How Plants Go Places.* Chicago: Scott, 1944.

WOOD, DOROTHY. *Plants with Seeds.* Chicago: Follett, 1963. 32 pp.

ZIM, HERBERT S. *Plants.* New York: Harcourt, 1947. 398 pp.

———. *What's Inside of Plants?* New York: Morrow, 1952. 32 pp.

ZIM, HERBERT S., and LESTER INGLE. *Seashores.* New York: Simon & Schuster, 1955. 160 pp.

ZIM, HERBERT S., and ALEXANDER C. MARTIN. *Flowers: A Guide to Familiar American Wildflowers.* New York: Simon & Schuster, 1950. 157 pp.

———. *Trees: A Guide to Familiar American Trees.* New York: Simon & Schuster, 1956. 160 pp.

CHAPTER

Animals 14

COMPOSITION AND CLASSIFICATION OF ANIMALS

I. The Cell

A. All animals, small or large, are made up of one or more cells.
   1. Cells are the smallest living parts of animals.
   2. Some tiny animals, such as the ameba, are made up of just one cell.
   3. Large animals, such as the elephant, are made up of billions of cells.

B. Each cell is filled with a living material, called **protoplasm.**
   1. Protoplasm is a jellylike material that often feels and looks like the white of an egg.
   2. Protoplasm is usually clear, but it can also have tiny bubbles, threads, or grains in it.
   3. It is usually colorless, but some protoplasm may appear gray, blue, or brown.

C. Inside the cell there is a ball-shaped body of heavier protoplasm, called the **nucleus.**
   1. The nucleus can be found in the center or at one end of the cell.
   2. The nucleus is surrounded by a thin covering, called the **nuclear membrane.**
   3. The nucleus controls and directs the activities of the cell.

D. The rest of the protoplasm around the nucleus is called **cytoplasm.**
   1. There are often tiny grains or threads in the cytoplasm.
   2. The cytoplasm may also have spaces or cavities, called **vacuoles,** in it.
   3. Some vacuoles store food, and others will have water or waste products in them.
   4. Many important life activities take place in the cytoplasm.

E. Each cell is surrounded by a thin covering, called the **cell membrane.**
   1. The cell membrane controls what enters and leaves the cell just as the nuclear membrane controls what enters and leaves the nucleus.
   2. Things like food and oxygen enter the cell through the cell membrane.
   3. Wastes like carbon dioxide leave the cell through the cell membrane.

F. Not all cells are alike.
   1. Many cells have special work to do so they differ in size and shape, and they may even have special materials.
   2. This difference makes it possible for the cells to carry on their special kind of activity or work.
   3. Examples of special cells include bone, muscle, skin, nerve, and blood cells.

G. A group of the same kind of cells that carry on the same activity or work is called a **tissue.**
   1. Examples of tissue include bone, muscle, skin, and nerve tissue.
   2. Even blood, which is a liquid, is a tissue.

H. A group of tissues working together is called an **organ.**
  1. Examples of organs include the heart, liver, stomach, kidneys, and brain.
  2. Organs carry out much more difficult tasks than tissues.

I. A group of organs that work together to carry out a special activity is called a **system.**
  1. The digestive system includes such organs as the esophagus, stomach, liver, and intestines.
  2. The circulatory system includes such organs as the heart, arteries, and veins.
  3. The respiratory system includes such organs as the windpipe, lungs, and bronchial tubes.

J. Cells, then, carry out all the activities that animals do in order to live.
  1. These activities are usually called **life processes.**
  2. Some of the more important life processes of animals include respiration, circulation, digestion, assimilation, excretion, growth, motion, and reproduction.

II. CLASSIFYING LIVING THINGS

A. All living things are grouped into two main divisions, called **kingdoms:** the **animal kingdom** and the **plant kingdom.**

B. These two kingdoms are subdivided into major groups, called **phyla.**
  1. Phyla are very large groups of animals and plants.
  2. All the members of a phylum have certain broad similarities in structure and in other characteristics.

C. The phyla are subdivided into smaller groups called **classes,** the classes into **orders,** the orders into **families,** the families into **genera,** the genera into **species,** and the species into **varieties.**
  1. A class is a finer subdivision of a phylum.
  2. An order is one of several groups within a class.
  3. A family is a group within an order.
  4. A genus is a smaller group within a family.
  5. A species is a group of very closely related animals.
  6. A variety is an individual of a species that differs slightly from other individuals in the same species, but not enough to be considered a separate species.

D. The further the phyla are subdivided into smaller groups, the greater the similarity there is among the members that make up each group.

E. When classifying living things, scientists give each phylum and its subgroups a scientific name made up of Latin words.
  1. This scientific naming makes the classification of each animal or plant definite, so that there can be no duplication.
  2. The scientific name also describes the animal or plant well enough so that it can be readily identified.
  3. The scientific name also helps show relationships between different animals or plants.
  4. Because Latin is a common language, the scientific names can be understood and used by people of all countries.

III. THE ANIMAL KINGDOM

A. Although scientists have classified animals into as many as 20 different phyla, the more well-known animals can be classified into just 10 phyla.

B. These 10 phyla include the **protozoans, poriferans coelenterates, platyhelminths, nemathelminths, annelids, echinoderms, mollusks, arthropods,** and **chordates.**

C. The animal kingdom is also commonly divided into two broad groups: animals with backbones and animals without backbones.
  1. Animals with backbones are called **vertebrates,** and animals without backbones are called **invertebrates.**
  2. Only the members of the chordate phylum are vertebrates.

3. The members of all the other phyla are invertebrates.

D. The cells of members of the animal kingdom are slightly different from the cells of the members of the plant kingdom.
1. In almost all cases, animal cells do not have chlorophyll.
2. Also, animal cells do not have a cell wall, made of cellulose, around them.

IV. The Protozoans

A. The protozoans are tiny, one-celled animals.
B. Some live as colonies, but each cell in the colony is an independent animal.
C. Examples of protozoans include the **ameba**, **paramecium**, and **euglena**.

V. The Poriferans

A. Poriferans are the simplest of the many-celled animals.
B. The body is a hollow tube with many pores or openings in it.
C. The wall of the body is made up of two layers of cells.
D. Saltwater and freshwater **sponges** belong to this phylum.

VI. The Coelenterates

A. The coelenterates are also made up of two layers of cells.
B. They have tentacles that surround their mouths, radiating out regularly like the spokes of a wheel.
C. Circulation and digestion take place in their hollow bodies.
D. Their bodies have an opening at one end only.
E. The **jellyfish**, **hydra**, **coral**, and **sea anemone** are members of this phylum.

VII. The Platyhelminths

A. The platyhelminths are flattened, ribbonlike worms, with bodies that are smooth and have no rings or body divisions, commonly called **segments**.
B. Their digestive tube has an opening at one end only.
C. They have very simple digestive and nervous systems.
D. Many of them are parasites.
1. Any living thing that lives on or in a plant or animal and gets its food from that plant or animal is called a **parasite**.
2. The plant or animal from which a parasite gets its food is called a **host**.

E. The **tapeworm**, **planaria**, and **fluke** belong to this phylum.

VIII. The Nemathelminths

A. The nemathelminths are worms with thin, round bodies with no rings or body divisions (segments).
B. Sometimes the bodies are threadlike.
C. They have definite digestive systems, and their digestive tube runs the length of the body with an opening at each end.
D. Many of these worms are parasites in animals and plants.
E. The **hookworm**, **pinworm**, and **trichinella** belong to this phylum.

IX. The Annelids

A. The annelids are worms with round bodies that are divided into rings or body divisions, called **segments**.
B. They have many well-developed organ systems.
C. The **earthworm**, **sandworm**, and **leech** belong to this phylum.

X. The Echinoderms

A. The echinoderms are animals with spines on their bodies.
B. They have a hard, shell-like kind of skeleton, which is on the outside of their body.
C. The parts of their body usually radiate out regularly from the center like the spokes of a wheel.

D. The **starfish, sea urchin, sand dollar,** and **sea cucumber** are members of this phylum.

XI. The Mollusks

A. The mollusks have soft, fleshy bodies with no segments.
B. Most mollusks have a protective shell made of lime.
   1. Because of this shell, mollusks are often called **shellfish.**
   2. They have a muscular foot and a special sheet of tissue, called the **mantle,** which produces the shell.
C. The **clam, oyster, scallop, snail, octopus,** and **squid** are members of this phylum.

XII. The Arthropods

A. The arthropods have skeletons on the outside of their bodies.
B. Their bodies are segmented and there are distinct body regions.
C. Their legs and all other parts that are attached to the body are jointed and can bend.
D. All the parts of their bodies are paired, and are arranged on the right and left sides of the body in such a way that one side of the body is a mirror image of the other side.
E. The **lobster, crayfish, crab, spider, tick, centipede, millipede,** and all **insects** are members of this phylum.

XIII. The Chordates

A. All chordates had a central nerve cord, called the **notochord,** before they were born.
B. Most chordates have a backbone, which replaced the notochord, and these chordates are called vertebrates.
C. Their skeletons are inside their bodies.
D. They all have two pairs of limbs attached to their body.
E. There are five important classes of chordates: **fish, amphibians, reptiles, birds,** and **mammals.**
F. Fish are cold-blooded animals.
   1. They have bony skeletons, and their bodies are covered with scales.
   2. They breathe by gills, and they have an air bladder that helps them rise or sink in the water.
G. Amphibians are cold-blooded animals.
   1. When they are young, they live under water and breathe by gills.
   2. Later, they change and develop lungs for breathing.
   3. They have a smooth skin without scales.
   4. Examples of amphibians include the frog, toad, and salamander.
H. Reptiles are cold-blooded animals.
   1. They breathe by lungs, and usually have a rough, scaly skin.
   2. Examples of reptiles include the snake, lizard, alligator, and turtle.
I. Birds are warm-blooded animals.
   1. They breathe by lungs.
   2. Their front limbs are called wings, and they are covered with feathers.
   3. Their legs are scaly.
   4. Their skeleton is light, hollow, and streamlined for flying.
J. Mammals are warm-blooded animals.
   1. They breathe by lungs.
   2. They usually give birth to living young, and suckle their young with milk from glands, called **mammary glands.**
   3. All mammals have hair on their bodies even though there may be just a few bristles, as is the case with the whale.
   4. All mammals have seven neck bones, but these bones are not the same size for all mammals.

ONE-CELLED ANIMALS

I. What One-Celled Animals Are

A. One-celled animals are the simplest animals known.

B. They are so small that most of them can be seen only with a microscope.

C. Although they are all made up of single cells, they can eat, breathe, move, and reproduce, just as larger animals do.

D. Although most one-celled animals live separately, some live together in colonies; however, usually each member in a colony lives independently of the other members.

E. One-celled animals live either in water or where conditions are moist.

1. Some live in fresh water, and others live in the ocean.
2. Some live in damp soil, and others live in decaying animal or plant matter.

F. One-celled animals are members of the animal phylum called **Protozoa.**

G. Examples of protozoans include the **ameba, paramecium,** and **euglena.**

II. The Ameba

A. The ameba is the simplest protozoan.

B. It can be found in the slime found on the bottom of ponds and rivers, and on the surface of the leaves of water plants.

C. Under the microscope it looks like a blob of grayish jelly with no definite shape.

D. The shape of the ameba keeps changing as it moves.

1. The ameba sends out fingerlike projections that are called **false feet,** or **pseudopodia.**
2. The rest of the ameba's body then flows into the false feet.

E. The ameba eats tiny plants, such as algae or bacteria.

1. When it touches food, the ameba sends out pseudopodia (false feet) that surround the food completely and take it into the cell.

F. There are tiny spaces or cavities, called **vacuoles,** in the ameba.

1. Some vacuoles have food in them.
2. One vacuole collects and gets rid of excess water, and possibly waste products as well, inside the ameba.

G. Oxygen in the water enters the ameba through the cell membrane (covering), and carbon dioxide produced by the digestion of food leaves the same way.

H. The ameba moves toward food, but away from bright light and chemicals, and it moves faster when the temperature becomes warmer.

I. The ameba reproduces by dividing into two equal parts, forming two new cells.

1. This method of reproduction is called **fission.**
2. First the nucleus divides, and the halves move to opposite ends of the cell.
3. Then the cell narrows in the middle and pulls apart so that two new cells are formed.

III. The Paramecium

A. The paramecium is a larger one-celled animal than the ameba.

B. It can be found in quiet ponds where a scum has formed on the surface.

C. It has a definite shape, and looks like a slipper or the sole of a shoe.

D. It is completely covered with fine, hairlike threads of protoplasm, called **cilia.**

1. These cilia constantly move back and forth in the water like tiny oars, making the paramecium move.
2. The paramecium can move forward or backward, and can also spin from side to side like a top.

E. The paramecium eats algae, bacteria, yeast, and other protozoans.

1. The action of the cilia forces the food into a small opening that acts as a mouth.

2. The food then passes into a narrow tube, called the **gullet**, which leads into the protoplasm of the cell.
3. The food is then held in vacuoles (cavities) for digestion.
4. The paramecium also has two vacuoles, one at each end of the cell, that get rid of excess water and some of the waste products.

F. Oxygen from the water enters through the cell membrane, and carbon dioxide produced by digestion of food leaves the same way.

G. There are two kinds of nuclei in the paramecium: large and small.
1. The large nucleus controls and directs the regular activities of the cell.
2. The small nucleus operates when reproduction takes place.

H. The paramecium reproduces like the ameba, that is, by splitting in two (fission).
1. First the small nucleus splits, and each half moves to an end of the cell.
2. Then the large nucleus splits in the same way.
3. The cell narrows in the middle and separates, forming two new paramecia.

I. Occasionally, two paramecia come together and exchange nuclear material.
1. This process is called **conjugation.**
2. In conjugation no new paramecia are formed, but the original paramecia are given new vitality so that they can continue reproducing by fission.

IV. The Euglena

A. The euglena is especially interesting to scientists because it behaves both like a plant and an animal.

B. It lives in freshwater ponds and streams.

C. It has a shape like a pear, with one end rounded and the other end pointed.

D. At the rounded end is a single, long, whiplike lash, called the **flagellum**, which turns in a spiral motion and drives the euglena through the water.

E. The euglena has chlorophyll in it and carries on photosynthesis when in the presence of sunlight.

F. However, when there is no light or the light is very weak, the euglena behaves like an animal.
1. It then eats bacteria and other tiny bits of plants and animals.
2. The food materials pass into the euglena and are digested in exactly the same way as in the other protozoans.

G. The euglena has a bright red spot, called an **eyespot**, which is sensitive to light and may help direct the euglena toward sunlight.

H. The euglena reproduces by fission, splitting lengthwise into two, with one half receiving the flagellum and the other half growing a new one.

I. When conditions become unfavorable, the euglena (and many other protozoans as well) forms a protective covering, called a **cyst**, around its cell and loses its flagellum.
1. Inside this cyst the euglena can live through periods of hot or cold weather and through dryness.
2. When conditions become favorable again, the cyst breaks open and the euglena becomes an active Protozoan once more.

V. Spore-Forming Protozoans

A. Some protozoans reproduce by forming tiny, round bodies, called **spores**.
1. The nucleus of the cell divides into many small nuclei.
2. Parts of the protoplasm around the nucleus (cytoplasm) then surround each of the new nuclei to form spores.
3. Finally, the whole protozoan breaks up and releases these spores.
4. The spores then become new protozoans.

B. All spore-forming protozoans are parasites.

C. They have no organs for moving, but are carried along in water or in liquids such as blood.

D. Malaria is caused by a spore-forming protozoan.

VI. Protozoans Can Be Both Helpful and Harmful

A. Protozoans serve as food for fish and other water animals.

B. Protozoans help man because they eat large amounts of bacteria that may be harmful to man.

C. Some protozoans live in the intestines of termites and digest the food that the termites eat.

D. Some protozoans that live in the ocean have shells made of lime around their bodies.

1. When they die, the shells fall to the bottom of the ocean, accumulate, and eventually may harden into a form of limestone called **chalk.**
2. Chalk is white, and is used in making toothpowder, putty, and blackboard crayons.

E. Some protozoans cause serious diseases, such as malaria, African sleeping sickness, and amebic dysentery.

SIMPLE MANY-CELLED ANIMALS

I. Many-Celled Animals

A. Most animals are made up of many cells, rather than single cells like the protozoans.

B. The cells in these many-celled animals are not all alike, but are different and have special functions.

C. Some very simple many-celled animals have their cells arranged in just two layers.

D. Examples of such simple many-celled animals include the **sponge, hydra, jellyfish, sea anemone,** and **coral.**

II. The Sponges

A. The sponges are members of the animal phylum called **Porifera.**

B. Most sponges are found in the ocean, but there are also some freshwater sponges.

C. Sponges may be colored white, red, orange, yellow, brown, purple, black, and green.

D. They can live singly or in colonies.

E. A sponge's body is a hollow tube with many pores or openings in it.

1. Water is always flowing into and out of the hollow tube.
2. The water carries in food and oxygen for the sponge, and takes away carbon dioxide and other waste products.

F. Sponges eat tiny plants and animals.

G. Sponges have skeletons made of different kinds of materials.

1. Some skeletons are made of lime.
2. Some skeletons are made of silicon and look glassy.
3. The sponges we use for cleaning have skeletons made of a softer, flexible material, called **spongin.**
4. We use the skeleton part of the sponge because the living cells are first allowed to die and then are washed away.

H. Sponges can reproduce from sexual cells, called **gametes.**

1. These special cells produce male cells, called **sperm,** and female cells, called **eggs.**
2. A male cell (sperm) unites with, or fertilizes, a female cell (egg).
3. This fertilized egg (called a **zygote**) develops into a young sponge that can swim around in the water by means of long, whiplike threads, called **flagella.**
4. As the young sponges become older, they settle to the bottom of the ocean and become attached to a rock or other object.

I. Sponges can also reproduce by a process called **budding.**

1. A bud develops near the base of the sponge and grows into a new sponge.

2. Some grown buds stay attached to the parent sponge, but others break off and live independently.

J. When a live sponge is cut up into many pieces, each piece can grow into a new sponge.

K. Some sponges look green because they are living together with tiny green plants, called **algae.**

1. The algae have chlorophyll and make their food by photosynthesis, giving off oxygen which the sponges use.
2. The sponges give off carbon dioxide when they digest their food, and the algae use the carbon dioxide for photosynthesis.
3. This arrangement, where two living things live together and help each other, is called **symbiosis.**

III. The Hydra

A. The hydra is a member of the animal phylum called **Coelenterata.**

B. It is found only in fresh water, and is ⅛ to ¼ inch long.

C. Some hydras are white whereas others may be brown or green.

D. The hydra has a round, tubular body with an open mouth at one end.

E. Surrounding the mouth are six to ten tentacles, which radiate out like the spokes of a wheel.

1. The tentacles have stinging cells in them.
2. When tiny animals touch the tentacles, the stinging cells shoot out tiny threads with poison in them and paralyze or kill the animals.
3. Then the tentacles bend inward and push these animals through the hydra's mouth and into the hollow body.
4. Cells inside the hollow body digest the animals, and any waste products pass out through the mouth.

F. The hydra attaches itself to rocks or water plants at its closed end.

1. The hydra can move by leaving the point where it is attached, floating in the water, and then attaching itself at another point.
2. It can also move by turning "handsprings," in which the body bends over, the tentacles touch the ground, and then the body swings up and over.

G. When the hydra is disturbed or irritated, the tentacles and body quickly contract.

H. The hydra can reproduce by budding.

1. A bud grows from the side of the body and grows into a new hydra.
2. The new hydra then separates from its parent and lives independently.

I. The hydra can also reproduce sexually, usually in the autumn.

1. The hydra develops a swelling, called a **testis,** with many sperm in it.
2. Another hydra, or sometimes the same hydra, produces a swelling, called an **ovary,** with an egg in it.
3. The sperm leave the testis and swim to the ovary.
4. When a sperm unites with, or fertilizes, the egg in an ovary, the fertilized egg grows into a new hydra.

J. Like the sponge, when a hydra is cut up into little pieces, each piece will grow into a new hydra.

K. Also like the sponges, some hydras look green because they are living in symbiosis with green algae.

IV. The Jellyfish

A. The jellyfish is also a member of the Coelenterata phylum.

B. They live only in seawater, and most of them are transparent.

C. Some jellyfish are very tiny, whereas others can be as wide as 7 feet across.

D. The body of the jellyfish is shaped like an open umbrella or parachute.

1. Between the two cells of the body there is a jellylike material, which gives the jellyfish its name.
2. The mouth of the jellyfish is on the underside of the body, and is usually surrounded by four tentacles.

3. The tentacles in very large jellyfish can be more than 50 feet long.
4. The tentacles have stinging cells in them.

E. The jellyfish cannot move very efficiently.
1. It moves by waving its body and contracting its tentacles.
2. It either floats or swims near the surface of the water.

F. It eats small fish and other sea animals, which swim into its tentacles and are stung.

V. Sea Anemones

A. The sea anemone is also a coelenterate.
B. Sea anemones look like king-sized hydras, but have hundreds of short tentacles around their mouths.
C. Many are brightly colored and look like the beautiful anemone flowers found on land.
D. They can often be seen along some seacoasts at low tide.

VI. Coral

A. The coral is a coelenterate that lives in large colonies.
B. Corals live in seawater, and are most common where the water is warm and shallow.
C. A coral looks like a hydra, but it is just a little larger.
D. Each coral builds a skeleton of limestone around it, taking the limestone from the seawater.
1. Each skeleton is connected firmly to the skeletons around it, making one big mass.
2. The coral's body and tentacles usually extend beyond the skeleton.
3. When the coral is disturbed, it can withdraw its tentacles and shorten its body so that the entire body can be contained inside its skeleton.
4. When the coral dies, its skeleton remains.

E. Corals can reproduce by budding, and the new corals stay connected to the original ones.
F. Because of reproduction by budding, the mass of skeletons can become higher and wider until it forms a rocky ridge called a **reef**.
1. Reefs are usually under water, but some protrude above the water, either temporarily at low tide or permanently when changes take place inside the earth that make the sea level lower.
2. Coral reefs are commonly formed near islands, where the water is rather shallow.
3. Some reefs even circle a small island.
4. Sometimes a circular reef with open water in the center is formed, and this kind of reef is called an **atoll**.

G. Corals can also reproduce sexually.
H. A young coral can swim about freely, but when it gets older, it becomes attached to the sea bottom or to some object and does not move around any more.
I. Coral is made into jewelry, and is also used for decoration in homes and stores.
J. Crushed coral is sometimes used in building roads and highways.

WORMS

I. Kinds of Worms

A. To many persons the word "worm" means something that is long, has a soft, ringed body, and wiggles.
B. However, not all worms are the same.
C. Scientists divide worms into three large groups: **flatworms, roundworms,** and **segmented worms.**
D. These three groups of worms are members of separate phyla, and are completely different from one another.

II. Flatworms

A. Flatworms are members of the animal phylum called **Platyhelminthes.**

B. They are the simplest of all the worms.
1. Their bodies are flat and ribbonlike, with none of the rings or body divisions that are commonly called **segments.**
2. The bodies are made up of only three layers of cells.

C. Some flatworms move about freely in water and get their food from the water.

D. Other flatworms live as parasites in larger animals, getting their food from the animal, which is called the **host.**

E. The **planaria** is a flatworm that is free-living (not parasitic).
1. It is usually found under stones in ponds and streams.
2. It is $\frac{1}{8}$ to $\frac{1}{2}$ inch long, and may be colored brown, black, or white.
3. The planaria's head is shaped like a spear, and there are two **eyespots** on the head, making the planaria appear to be cross-eyed.
4. These eyespots are sensitive to light, and the planaria moves away from bright light.
5. The planaria's mouth is in the middle of its body, on the underside, attached to a tube that sometimes sticks out of the body when the planaria is looking for or is feeding on food.
6. The planaria has a simple digestive system that is open only at one end; thus food enters and waste materials pass out from the same end.
7. The planaria lives on tiny water animals and also on dead plant and animal matter.
8. It also has a simple nervous system.
9. It moves by means of two layers of muscles under its skin, and also by many tiny hairs, called **cilia,** on its underside.
10. The planaria can reproduce by fission (splitting in two).
11. It can also reproduce sexually, with each planaria having both male cells (sperm) and female cells (eggs) in it.
12. When a planaria is cut up into many pieces, each piece will form a new planaria.

F. The **tapeworm** is perhaps the most well-known parasitic flatworm.
1. As a parasite, it lives in and gets its food from an animal, which is called the **host.**
2. Man sometimes has a tapeworm because he has eaten meat that has not been cooked thoroughly.
3. A tapeworm has a knob-shaped head with suckers, and sometimes hooks as well, on it.
4. The suckers and hooks help the tapeworm clamp itself to the wall of a human's intestine.
5. The parasite has no mouth or intestine, and the digested food from the human's intestine passes directly into the tapeworm's head.
6. The tapeworm has no eyes, and it does not move.
7. Sections keep forming just back of the tapeworm's head.
8. As more new sections form, the older sections are pushed farther and farther back.
9. As a result, the worm gets to look like a long piece of tape.
10. Sometimes there are more than 200 sections to a tapeworm's body, and the tapeworm can be more than 50 feet long.
11. The end sections of the tapeworm's body grow larger and older, and then drop off and pass out of the human's body.
12. The sections that drop off are filled with egg cells that have already been fertilized because each section of the tapeworm is able to produce both male cells (sperm) and female cells (eggs).
13. The sections that drop off soon decay, but the fertilized eggs stay alive.
14. When these eggs are eaten by an animal, such as the cow or pig, with its

food, the eggs grow into tiny young tapeworms.
15. These young tapeworms cannot grow any larger and become adults until they enter the body of a human again.
16. They worm their way into some tissue, such as the muscle or liver, of the animal.
17. Inside the tissue each young tapeworm forms a capsule, called a **cyst**, around itself.
18. Inside the cyst the tiny tapeworm forms a head (with suckers) and a few sections, and then stops and rests or waits until the meat of the animal is eaten by a human.
19. If the animal's meat is not thoroughly cooked, a young tapeworm that is still alive can come out of its cyst, clamp onto the human's intestine, and grow into an adult tapeworm.
20. When segments from the new tapeworm drop off and pass out of the human's body, the whole life cycle of the tapeworm starts again.
21. During its life cycle the tapeworm has two hosts.
22. The host for the adult tapeworm is called the **primary host**, and the host for the young tapeworm is called the **secondary host.**

G. The **fluke** is another well-known parasitic flatworm.
1. Flukes are very dangerous to many animals and also to man.
2. They live in such organs as the stomach, intestine, liver, or lung, where they damage or destroy the lining tissues of these organs and cause loss of blood and ulcers.
3. Many of the flukes look somewhat like the planaria.
4. Almost all of the flukes have more than one host during their life cycle, and one of the fluke's secondary hosts is always a snail.
5. Fluke infections are most common in Africa and Asia.

III. Roundworms

A. Roundworms are members of the animal phylum called **Nemathelminthes.**

B. They have thin, round, smooth bodies that are not divided into rings or segments.

C. They have a complete digestive system, with a mouth at the front end and an opening, called the **anus**, at the rear end.

D. Some roundworms are free-living (nonparasitic).
1. They live in the soil, fresh water, or salt water.
2. Free-living roundworms are very tiny, and are harmless.

E. Some roundworms are parasitic, and live in animals or plants.
1. They can be as long as 4 feet.
2. Different kinds of parasitic roundworms have already infected about one third of the human race.

F. The most common parasitic roundworm is the **ascaris.**
1. It is a large worm, and lives in the intestine of larger animals, such as the pig and the horse, and sometimes in man.
2. It feeds on the partly digested food in the intestine.
3. Ascaris worms lay millions of eggs, which pass out of the body with the waste products.
4. In regions where there is no modern sanitary sewage disposal, these eggs are deposited in water, soil, and food grown on that soil.
5. The eggs then enter and infect other animal and human bodies through the contaminated food or water.
6. Most infections caused by ascaris worms are not serious.
7. However, sometimes such large masses of these worms form that they block the intestine and death results.
8. Sometimes the adult worms bore through the intestine, travel through the body, and go into vital organs, such as the liver, causing death.

G. The **hookworm** is a parasitic roundworm that is a serious health menace to man.
1. It is found in all tropical and semi-tropical regions, as well as in the south-eastern United States, wherever there are unsanitary sewage disposal conditions.
2. Hookworms are quite small, less than ½ inch, and thousands can live in the intestine at one time.
3. The adult hookworms attach themselves to the wall of the intestine by their hooklike teeth and suck the blood from the intestine wall.
4. This steady loss of blood makes the hosts tired and anemic.
5. In the intestines the worms reproduce and lay eggs, which pass out of the body with the waste products.
6. The eggs hatch in the soil and grow into young hookworms.
7. These young hookworms enter the body of animals and humans by boring through the skin, usually at the feet.
8. Once they enter the body, they travel in the blood to the lungs.
9. In the lungs they pass through the air passages and move up the windpipe into the throat.
10. In the throat they are swallowed and pass through the stomach into the intestine, where they attach themselves and grow into adult hookworms, producing more eggs for possible future infection.

H. The **trichinella** is a parasitic roundworm that can cripple and even kill a human.
1. It lives in the intestine of its host, which can be an animal or a human.
2. Each trichinella can produce as many as 2000 eggs.
3. These eggs hatch into young worms, which travel in the blood to muscles all over the body.
4. The young worms bore into the muscles and form tiny capsules, called **cysts**, around themselves.
5. The young worms stay inside these cysts and cannot grow into adults until the flesh of the host is eaten by another animal or by a human.
6. When another animal or man eats this infected meat, the young worms come out of their cysts, become adult worms, and start producing their own young worms.
7. These young worms find their way to the muscles of their hosts and form cysts there.
8. Man becomes infected by the trichinella from eating undercooked meat of an animal that is a host to the trichinella.
9. Usually this animal is the pig, and the meat is pork.
10. The pig gets the trichinella by eating garbage that has scraps of raw meat with trichinella worm cysts in them.
11. When a human is infected with the trichinella, the muscles become inflamed and painful as the young worms are boring their way into the muscles and forming cysts.
12. If too many worms find their way into the muscles, the person may become crippled or may even die.
13. Once the worms find their way into the muscles there is no way to remove them because they are very tiny.
14. The disease caused by the trichinella is called **trichinosis**.

IV. Segmented Worms

A. Segmented worms are members of the animal phylum called **Annelida**.

B. Annelids are the most highly developed group of worms.
1. Their bodies are divided into many rings or sections, called **segments**.
2. They have many well-developed organ systems, which include a digestive system, a circulatory system with blood and blood vessels, an excretory system for getting rid of waste matter, a nervous system, and a reproductive system.

C. Segmented worms can be found in salt

water, in fresh water, and in the soil.

D. The earthworm is a common segmented worm that lives in the soil.
   1. Its front end is darker and more pointed than its tail.
   2. Four bristles, called **setae**, stick out from the sides and underside of each body segment, except the first and the last segments.
   3. These bristles help the earthworm move.
   4. The earthworm is able to move because it has two sets of muscles: one set that can make the earthworm long and thin, and another set that can make the earthworm short and thick.
   5. The earthworm has no respiratory system, but absorbs oxygen and gives off carbon dioxide through its thin skin, which must be kept moist.
   6. Each earthworm forms both sperm and eggs, but the eggs of one worm can only be fertilized by the sperm of another worm.
   7. As a result, two earthworms come together and exchange sperm so that the eggs in each earthworm can be fertilized.
   8. The earthworm lays a batch of fertilized eggs in the soil, which eventually hatch and become young earthworms.
   9. The earthworm eats dirt, digesting the decayed plant and animal matter from the dirt and eliminating the rest.
   10. Earthworms are valuable to man because they bore holes and loosen the soil so that air and water can enter the soil and help plant roots grow.
   11. Many scientists believe that the waste matter that passes out of the earthworm's body makes a good fertilizer.

E. The **sandworm** is a segmented worm that lives in the ocean near the shore.
   1. It is more active than the earthworm.
   2. It has four eyespots that are sensitive to light, and a group of tentacles on its head.
   3. Sometimes the sandworm burrows into the sand, with only its head exposed to the water.
   4. The sandworm can also swim about in the water, helped by little projections on each side of its body.
   5. The sandworm eats tiny saltwater animals.

F. The **leech** is a parasitic segmented worm.
   1. Most leeches are found in fresh water, but a few live in the ocean.
   2. They are commonly called "bloodsuckers" because they live by sucking the blood of larger water animals, such as fish and turtles.
   3. A leech has two suckers, one at each end of its body, for clinging to these water animals.
   4. It uses the rear sucker to attach itself to the animal's body.
   5. Then it attaches the front sucker to another part of the animal's body, and breaks the skin of the animal with sharp little jaws in its mouth.
   6. A substance in the saliva of the leech prevents the animal's blood from clotting while the leech is sucking the blood of its victim.

SPINY ANIMALS

I. What Spiny Animals Are

A. Spiny animals are members of the animal phylum called **Echinodermata.**

B. All the echinoderms live only in the ocean.

C. They all have a hard, shell-like kind of skeleton, which is on the outside of their bodies.

D. Almost all of them have some kind of spines on their bodies.

E. The parts of their bodies usually radiate out regularly, like the spokes of a wheel.

F. Members of this phylum include the starfish, sea urchin, sand dollar, and sea cucumber.

II. The Starfish

A. The starfish is not a fish at all.

B. It has no head, but is made up of a circle of arms that come together at the center of its body, forming a star shape.

1. Most starfish have five arms, but some have six or more arms.
2. There are spines all over the body and arms.
3. The stomach of the starfish is at the center of the body, and its mouth is on the underside.

C. A starfish eats clams and oysters.

1. On the underside of each arm there are hundreds of little tubes, called **tube feet.**
2. Each tube foot acts as a vacuum or suction cup and can stick firmly to any object on which it is pressed.
3. The starfish crawls over the top of a clam and presses its tube feet firmly on both sides of the shell.
4. The starfish pulls on the clam until the clam becomes tired and opens its shell.
5. Then the starfish turns its stomach inside out so that the stomach extends through the mouth, and it digests the clam's body.

D. The starfish can crawl in any direction.

1. An eyespot at the end of each arm is sensitive to light.
2. The starfish moves about mostly at night.

E. Starfish are either male or female.

1. They discharge their sperm and eggs into the water, where fertilization of the eggs takes place.
2. A female starfish may lay more than 100 million eggs in one season.

F. Starfish can grow new parts.

1. If a starfish loses an arm, it can grow a new one.
2. If a starfish is chopped into three or four pieces, and if each piece has at least one arm and also part of the center of the body, each piece may grow into a new starfish.

III. Other Echinoderms

A. The **sea urchin** is a globe-shaped echinoderm with very long spines.

B. The **sand dollar** is very much like the sea urchin, but it is very flat and its spines are very short.

C. The **sea cucumber** is long and soft, and really looks like a cucumber growing under water.

SHELLFISH

I. What Shellfish Are

A. Shellfish are members of the animal phylum called **Mollusca.**

B. The word "shellfish" is a poor name for the mollusks.

1. Mollusks are not fish.
2. Not all of them have shells.
3. Many live on land.

C. All mollusks have thick, soft, fleshy bodies.

D. Mollusks are divided into three large groups, which are commonly called **hatchet-footed, belly-footed,** and **head-footed** mollusks.

1. The hatchet-footed mollusks live inside two shells that are connected by a muscular hinge which can open and close the shells.
2. The belly-footed mollusks have just one spiral shell and seem to be moving on

their bellies, carrying their shells on their backs.

3. The head-footed mollusks have a definite head, surrounded by many arms called **tentacles.**

II. The Hatchet-Footed or Bivalve Mollusks

A. The hatchet-footed mollusks all have two shells, called **valves,** which are connected by a muscular hinge.
   1. Because of these two shells or valves, they are usually called **bivalve** mollusks.
   2. The muscular hinge opens and closes these shells.
   3. Bivalves never shed their shells, and the shells become larger as the bivalve grows.
   4. Lines on the outside of the shell tell roughly the age of the bivalve, each line representing a year's growth.

B. Bivalve mollusks include the **clam, oyster, scallop,** and **mussel.**

C. They all live in the ocean, but the clam can be found both in salt water and fresh water.

D. They all have a tough muscular foot, shaped somewhat like a hatchet, which sticks out from the shells and is used for digging.

E. The inside of their shells are lined with a special sheet of tissue, called the **mantle,** which produces the shell.

F. They have two tubes, called **siphons.**
   1. Water carrying oxygen and food flows into one siphon.
   2. Water carrying carbon dioxide and waste products flows out of the other siphon.

G. They have respiratory or breathing organs, called **gills,** which allow oxygen to enter the body and carbon dioxide to leave.

H. They have a well-developed digestive system, excretory system for getting rid of wastes, nervous system for controlling their movements, reproductive system, and a circulatory system with a heart, blood, and blood vessels.

I. Bivalve mollusks are either male or female, and reproduce sexually.

J. In the ocean the oyster and many kinds of clams do not move at all, but are attached to a rock or some other object.

K. In the South Pacific Ocean there are clams as large as 6 feet across.

III. The Belly-Footed or Univalve Mollusks

A. The belly-footed mollusks have one shell or valve, which is usually shaped in a spiral.

B. Because of the one shell or valve, they are usually called **univalve** mollusks.

C. Univalves include the **snail, slug, periwinkle, conch,** and **abalone.**

D. The conch and abalone live in the ocean whereas the slug lives on land, and there are both land snails and water snails.

E. Univalves all have the same vital body organs as the bivalves, except that some snails have lungs instead of gills for breathing.

F. Univalves also have a much larger foot than bivalves.
   1. This large foot looks like part of the univalve's body to most people, and, therefore, they think the univalve is crawling on its belly and carrying its shell on its back.
   2. When the univalve is attacked, it pulls its foot and head up inside its body.

G. The snail has two tentacles on its head.
   1. Some snails have an eye on the tip of each tentacle.
   2. When the snail is touched, it draws in its tentacles.

H. The slug does not have a shell and looks like a snail that has lost its shell.

I. The foot of land snails and slugs gives off a kind of slime, and the snails and slugs move only on this slime.

J. Snails and slugs also have a tonguelike structure that is very rough.
   1. This "tongue" moves in and out, and acts very much like a file to scrape off bits of food.

2. Land snails and slugs use this tongue to eat plants.
3. Water snails help keep an aquarium clean by using their scraping tongue to eat algae, bacteria, and dead or decaying materials that collect on the glass sides of the aquarium.

IV. The Head-Footed Mollusks

A. The head-footed mollusks include the **octopus** and the **squid**.
B. They have the same parts and organs as the other mollusks, but arranged differently.
C. Both the squid and the octopus live in the ocean.
D. The squid has a long, narrow, torpedo-like body.
   1. It has no shell on the outside.
   2. Its foot is divided into two long and eight short tentacles, which have double rows of suction cups on them for grasping objects firmly.
   3. It has a large eye on each side of its head.
   4. It also has a sharp beak, which it uses to bite off pieces of food.
   5. Most squids are no more than 3 or 4 feet long, but there are some giant squids that are at least 60 feet long.
E. The octopus is built much like the squid, but its body is short and rounded.
   1. It has only eight tentacles, all the same size.
   2. It has a shell, but the shell is inside its body.
   3. It has eyes and a sharp beak, just like the squid.
   4. Some octopuses have tentacles 6 inches long, but others may have tentacles 15 feet long.
F. When attacking or being attacked, the squid and octopus can shoot out an inky material that makes the water cloudy.

V. Importance of Mollusks

A. Clams, oysters, scallops, snails, and abalones are all eaten by man.
B. Octopuses and squids are eaten by man in some parts of the world, and very often they are cut up and used as bait by fishermen.
C. The inner surface of clam and oyster shells are used to make buttons and mother-of-pearl.
D. Shells are also ground up and sold to farmers for chicken feed because the lime in the shells is needed by the chickens for making egg shells.
E. Certain oysters make pearls.
   1. A pearl is formed when an irritating object, such as a parasitic worm, gets inside the flesh of the oyster and forms a tiny round capsule, called a cyst.
   2. The mantle (shell-producing tissue) forms layers of shell material around the cyst, producing the pearl.
F. The Japanese have discovered a way of making the oyster form a pearl.
   1. They take a small round bead made from shell, cover the bead with living mantle cells, and push the bead inside the oyster.
   2. The oyster is then put into the ocean for a few years and a pearl forms around the head.
   3. This pearl, which is called a **cultured pearl**, looks just like a natural pearl.

CRAYFISH, LOBSTERS, CRABS, AND SHRIMPS

I. What Crayfish, Lobsters, Crabs, and Shrimps Are

A. The crayfish, **lobster, crab, shrimp,** the tiny water **flea, sowbug,** and **pill bug** are all members of the very large animal phylum called **Arthropoda.**

B. Together they form a special class of arthropods called **Crustacea.**

C. All arthropods have the following similar characteristics.

1. They have an outside skeleton, made of a tough material, called **chitin,** which covers their bodies and has joints that can bend.
2. The muscles of the body are attached to the inside of the skeleton.
3. Their legs and the other parts that are attached to the body, all of which are called **appendages,** are also jointed and can bend.
4. Their bodies are segmented, and there are distinct body regions.
5. They have **bilateral symmetry,** which means that all the parts of their bodies are paired, being arranged on the right and left side of the body in such a way that one side of the body is a mirror image of the other side.

D. In addition to having the characteristics of all arthropods, the crustaceans have their own special characteristics.

1. They have two pairs of feelers, called **antennae.**
2. Their outer skeleton has a chemical called lime in it.
3. They all have two very distinct body regions.
4. Almost all of them live in saltwater or freshwater.
5. Many of them have special breathing organs, called **gills,** which allow oxygen to enter their bodies and carbon dioxide to leave.

II. The Crayfish

A. The crayfish is a good example of a typical crustacean.

B. It has a dark outer skeleton with lime in it.

C. It has two distinct body regions: the **cephalothorax** and the **abdomen.**

1. The cephalothorax is really made up of two regions: the head and the chest, or **thorax,** both grown together so that they look like one region.
2. The abdomen, commonly called the tail, is made up of seven movable segments.

D. The cephalothorax is covered by a hard shell, called the **carapace,** which gives the crayfish extra protection.

E. The crayfish has two eyes, one on each side of the front part of the cephalothorax.

1. The eyes are set on the ends of short, movable stalks.
2. Each eye is made up of many lenses, and for this reason it is called a **compound eye.**

F. The crayfish has two pairs of long feelers, called **antennae,** and several smaller feelers, called **antennules.**

G. It has six pairs of mouth parts.

1. Three pairs are connected to the head, and three pairs are connected to the chest, or thorax.
2. These mouth parts are used for holding food, cutting and grinding it, and pushing it into the mouth.

H. It has five pairs of legs, all connected to its chest, or thorax.

1. The first pair, called the **chelipeds,** is much larger than the other four pairs, and one cheliped is always larger than the other.
2. The chelipeds have large pincers, which are used for grabbing and holding food.
3. The remaining four pairs of legs are used mostly for walking.
4. Two pairs of these walking legs end in

tiny pincers, and two pairs end in tiny claws.

I. It has six parts of appendages, called **swimmerets**, on its abdomen.

1. Each segment of the abdomen has a pair of swimmerets, except for the last segment, which has nothing.
2. The first five pairs of swimmerets are quite small, being used by the female for carrying her eggs until they are hatched, and by both the male and female for slow, forward swimming.
3. The sixth pair of swimmerets is large and paddlelike; these swimmerets are called **uropods.**
4. The uropods and the seventh segment of the abdomen; called the **telson,** together make up the tail of the crayfish.

J. The crayfish usually moves backward, using its sixth and seventh abdomen segments and its four walking legs.

1. These appendages make it possible for the crayfish to move backward easily and swiftly.
2. The crayfish also uses its four walking legs to travel forward and sideways.

K. The crayfish breathes through special feathery organs, called **gills.**

1. These gills are attached to the five pairs of legs and the three pairs of mouth parts that are connected to the thorax.
2. The gills allow oxygen in the water to enter the body of the crayfish and carbon dioxide to leave.

L. The crayfish is a freshwater animal, living at the bottom of lakes, ponds, and streams.

M. It eats plants and any live or dead animal material it can grasp.

N. The crayfish breeds just once a year.

1. The female mates with the male in the autumn.
2. In the spring the female lays about 100 eggs, which are attached to the first five pairs of spinnerets on her abdomen.
3. The female carries these eggs until they hatch.
4. The young crayfish stay attached to the swimmerets for about 2 weeks, holding the hairs of the swimmerets with their pincers.
5. During this time the young crayfish feed on the yolk that was in the eggs.
6. After 2 weeks the young crayfish let go of the swimmerets and are now independent, growing up to be adult crayfish.

O. When a crayfish grows larger, it sheds its skeleton.

1. This process is called **molting.**
2. Because the shell is rigid and cannot stretch, the crayfish cannot grow larger unless it gets rid of its skeleton.
3. Most crayfish molt about seven times the first year, and once or twice a year thereafter.
4. While a crayfish is molting, it is quite defenseless, so it usually goes into hiding until the new skeleton is formed.

P. If the crayfish should lose one or more of its appendages during molting or in a battle, it can regenerate or grow new appendages to replace the lost ones.

III. The Lobster

A. The lobster is built like the crayfish, except that the lobster lives in saltwater and is much larger.

B. One kind of lobster is exactly like the crayfish, and is found in the North Atlantic Ocean.

C. Another kind of lobster does not have the first pair of large legs (chelipeds), and is found along the coast of Florida, California, and the West Indies.

IV. The Crab

A. The body of a crab is wide and round rather than long and narrow like the crayfish and the lobster.

B. The crab's abdomen is very small and folds under the broad shell (cephalothorax).

C. Crabs move by walking sideways.

D. "Soft-shell" crabs are crabs that were caught just after they had molted.

V. The Shrimp

A. The shrimp is like the crayfish, lobster, and crab.
B. However, the shrimp has five walking legs and a very large, muscular abdomen.
C. The shrimp can swim very fast, moving backward like the crayfish and lobster.
D. When the shrimp is frightened, it buries itself in the sand, with only its antennae and eyes exposed.

VI. Economic Importance

A. Crayfish, lobsters, crabs, and shrimps are widely used as food.
B. They are also useful as scavengers because they eat dead animals.

INSECTS

I. What Insects Are

A. Insects are members of the very large animal phylum called **Arthropoda.**
B. All the insects together form a special class of arthropods called **Insecta.**
C. Insects have the characteristics common to all arthropods.
   1. They have an outside skeleton made of a tough material, called **chitin.**
   2. Their legs and other parts attached to the body, all of which are called **appendages,** are jointed and can bend.
   3. Their bodies are segmented, and there are distinct body regions.
   4. They have **bilateral symmetry,** which means that all the parts of their body are paired, being arranged on the right and left side of the body in such a way that one side of the body is a mirror image of the other side.
D. In addition to having the characteristics of all arthropods, insects have their own special characteristics.
   1. They all have three separate body regions: the **head, thorax,** and **abdomen.**
   2. They have one pair of feelers, called **antennae,** attached to their heads.
   3. They have three pairs of legs, all attached to the thorax.
   4. Most insects have one or two pairs of wings, also attached to the thorax.
   5. Most adult insects have both **simple eyes,** which are made up of just one lens, and **compound eyes,** which are made up of many single lenses.
   6. Almost all of the insects live on land.
   7. They breathe through branching tubes, called **tracheae,** which are connected to tiny outside openings, called **spiracles,** on each side of the abdomen and thorax.
E. Insects make up the largest class in the animal kingdom.
   1. There are about 700,000 different kinds (species) of insects that have already been classified, and scientists believe that this is less than half the total number on earth.
   2. Each kind produces thousands of young insects.
F. Insects are more highly specialized than man.
   1. Because of the way they are built, insects are able to adjust to their environment very well.
   2. As a result, they have been very successful in their struggle for existence, and have lived on earth much longer than man.

II. Metamorphosis in Insects

A. All insects develop from eggs.
B. However, from the time the eggs hatch until the young insects become fully grown adults, most insects pass through a series

of forms or stages, called **metamorphosis.**

C. There are two kinds of metamorphosis: **incomplete metamorphosis** and **complete metamorphosis.**

D. Insects like the grasshopper, cricket, dragonfly, true bug, aphid, and termite undergo incomplete metamorphosis.

1. Incomplete metamorphosis has three forms or stages: egg, **nymph,** and **adult.**
2. The nymph hatches from the egg and looks just like the adult except that it does not have wings and mature sex organs.
3. When it is first hatched, the nymph is only as large as the egg, and its head is much larger than its body.
4. The nymph eats and grows, but its outside skeleton does not grow as fast as the nymph itself.
5. As a result, from time to time the nymph rests, splits and sheds its skeleton, and then continues to grow a new, larger skeleton.
6. The shedding of the skeleton is called **molting,** and usually takes place about five times before the nymph becomes an adult insect.
7. After each molting the nymph looks and becomes more like the adult insect.
8. After the final molting the nymph becomes a fully grown adult.

E. Insects like the butterfly, moth, bee, ant, beetle, fly, and mosquito undergo complete metamorphosis.

1. Complete metamorphosis has four stages: egg, **larva, pupa,** and **adult.**
2. The larva hatches from the egg and looks like a segmented worm.
3. The larva eats and grows, and then stops from time to time to shed its skin (molt).
4. After each molting the larva does not change, but continues to eat and become larger.
5. After several moltings the larva goes into the pupa stage, which is commonly called the resting stage.
6. However, although there is no movement during the pupa stage, a remarkable change takes place.
7. In the pupa stage all the tissues of the larva are changed into those of an adult insect.
8. When the pupa stage is completed, a fully grown adult insect has been formed.

III. Kinds of Insects

A. Biologists divide all insects into about 25 different groups, called **orders.**

B. The division of insects into orders is based, for the most part, on the kind of mouth parts, wings, and metamorphosis the insects have.

C. The following eight insect orders are quite common in the United States: the **grasshopper** order, the **dragonfly** order, the **beetle** order, the **true bug** order, the **aphid** order, the **butterfly** and **moth** order, the **fly** and **mosquito** order, and the bee and **ant** order.

IV. The Grasshopper Order

A. The grasshopper, cricket, praying mantis, katydid, walking stick, locust, and cockroach belong to this order.

B. They have mouth parts that are designed for chewing with hard jaws that move from side to side instead of up and down.

C. They have two pairs of wings.

1. The front wings are long, narrow, and like stiff paper.
2. The back wings look like cellophane and are wide, thin, and veined.
3. When not in use, the back wings fold up lengthwise like a fan under the front wings.

D. In some of these insects, like the grasshopper, the rear legs are large and highly developed for jumping.

E. The grasshopper makes sounds by rubbing a row of spines on its rear leg against a wing vein.

F. All the insects of the grasshopper order undergo incomplete metamorphosis.

G. The grasshopper and cricket are very destructive insects, eating pasture and grain crops.
H. The praying mantis is the only insect in this group that is useful to man; it eats other insects, many of which are harmful to man.

V. The Dragonfly Order

A. The dragonfly and damselfly belong to this order.
B. They have long, thin bodies and are often called "needles."
C. They have chewing mouth parts.
D. They have two pairs of wings.
   1. The wings are thin, like cellophane.
   2. They do not fold but stick straight out from the body, one pair below the other.
E. They undergo incomplete metamorphosis.
F. The larva form of these insects lives in the water and eats the larvae of other insects.
G. The adult dragonfly and damselfly eat mosquitoes, gnats and other insects.

VI. The Beetle Order

A. The Japanese beetle, potato beetle, wood-boring beetle, boll weevil, ladybug, and carrion beetle belong to this order.
B. They have chewing mouth parts.
C. They have two pairs of wings.
   1. The front wings are very hard and meet in a straight line down the back.
   2. The front wings fit closely over the body and look very much like a shell.
   3. The back wings are thin and fold under the front wings.
   4. Because of the hard front wings, these insects make a whirring noise when flying.
D. They undergo complete metamorphosis, and their larvae are commonly called grubs.
E. The potato bug destroys potato plants, the boll weevil destroys grain and cotton, and the Japanese beetle destroys the fruit and leaves of trees, shrubs, and grasses.
F. The ladybug eats many harmful insects, and the carrion beetle acts as a scavenger by feeding on dead animals.

VII. The True Bug Order

A. Many persons use the word *bug* for most insects, but to scientists the word *bug* refers to a special order of insects.
B. The bedbug, stinkbug, squash bug, and water bug belong to this order.
C. They have sucking mouth parts.
   1. They feed by sticking these parts into plants and sucking the plant juices.
   2. The bedbug sucks the blood of man, and is a carrier of disease as well.
D. Although one or two kinds of bugs have no wings, the rest have two pairs of wings.
   1. Both the front and back wings are thin.
   2. The edges of the wings overlap, and one half of the wing is thicker than the other.
E. They undergo incomplete metamorphosis.
F. Many of them are troublesome pests.

VIII. The Aphid Order

A. The aphid or plant louse, scale insect, mealy bug, leaf hopper, and cicada belong to this order.
B. They have sucking mouth parts, and feed on the juice of plants.
C. Some have two pairs of wings, but others are wingless.
   1. Those that have wings hold the wings over their body like an upside down **V** so that the wings look like the roof of a house.
   2. Both pairs of wings are thin.
D. They undergo incomplete metamorphosis.
E. Most of them do great damage to wild and garden plants.
F. The lac insect, however, gives us shellac, which is used in lacquers and wood finishes.

IX. The Butterfly and Moth Order

A. Butterflies and moths have sucking mouth parts.
1. Some moths have no mouths at all.
2. Other moths and all butterflies have a long, coiled tube, which they use to sip the sweet liquid, called nectar, inside the flowers.

B. They have two pairs of wings that are covered with tiny scales.
1. These scales produce the brilliant and beautiful colors in their wings.
2. Most butterflies and some moths have pretty wings, but many moths have single-colored, unattractive wings.

C. Butterflies and moths undergo complete metamorphosis, and their larvae are called caterpillars or worms.
1. The moth larva usually spins a strong silk case, called a **cocoon,** when it goes into the pupa (resting) stage.
2. The butterfly pupa, however, rests in a hardened case, called a **chrysalis.**

D. Many persons find it hard to distinguish between butterflies and moths, especially when they both have colored wings, but there are definite differences between them.
1. The butterfly usually has a thin abdomen; the moth usually has a fat abdomen.
2. The butterfly's antennae usually have knobs at their ends; the moth's antennae are usually feathery.
3. The butterfly usually flies during the day; the moth usually flies at night.
4. The butterfly's wings are usually vertical when at rest; the moth usually holds its wings horizontally when at rest.
5. The pupa of the butterfly rests in a chrysalis; the pupa of the moth usually rests in a cocoon.

E. Some butterflies and moths migrate, traveling to different parts of the country or world during different seasons of the year.
1. The monarch butterfly lives in northern United States during the summer.
2. In late summer they fly away in very large groups, some going to the Gulf states, and others going to the Pacific Coast.
3. They stay quietly in these places until the winter is over.
4. In the spring they all fly northward again.

F. The larvae of butterflies and especially moths are very destructive to man.
1. The apple worm, tomato worm, corn borer, cabbage worm, cotton boll weevil, and tobacco worm all eat and destroy vegetables and crops.
2. The larvae of the gypsy moth and browntail moth eat the leaves of forest and orchard trees, destroying them.
3. The larvae of the clothes moth feed on clothing, especially wool.

G. The silkworm moth is helpful because its larva spins a cocoon of silk threads, which we use to make silk cloth.

H. All butterflies and many moths help in the cross-pollination of flowers as they travel from flower to flower to obtain nectar.

X. The Fly and Mosquito Order

A. The housefly, tsetse fly, stable fly, and mosquito belong to this order.

B. They have sucking mouth parts.

C. They only have one pair of wings, which are thin and veined.

D. They undergo complete metamorphosis.

E. The housefly has large eyes, short antennae, and a bat-shaped sucking tube.
1. It does not bite, although other flies like the stable fly, or horsefly, and the tsetse fly bite both animals and man.
2. Its wings are highly developed and it can fly swiftly.
3. Its feet have claws and sticky hairs, which help it stay securely on walls and ceilings.
4. These sticky hairs only work well if they are free from dust; the fly is always cleaning its feet by rubbing one foot against the other.
5. The female fly lays its eggs in stable

manure or other similar matter, and the larvae that hatch are commonly called **maggots.**

6. The fly picks up all kinds of bacteria on its hairy feet and body.
7. When the fly lands on food that humans eat, some of the bacteria that cause typhoid fever, dysentery, and cholera can be left on the food.

F. The female mosquito lays its eggs in water, and the larvae that hatch are commonly called **wigglers.**

1. The pupa stage of the mosquito is different from most insect pupa stages because the mosquito pupa can move.
2. The adult mosquito has mouth parts that are designed for piercing and sucking.
3. The mosquito usually feeds on human and animal blood.
4. To make the sucking of blood easier and to prevent the blood from clotting, the mosquito injects a little of its saliva in the blood, causing the irritation and swelling that we call a "mosquito bite."
5. Some mosquitoes carry disease germs, such as malaria and yellow fever, in their bodies and spread these germs from person to person as they bite and suck up the blood.

XI. The Bee Order

A. Although most insects live alone, certain kinds of insects live together in large groups or communities, called **colonies.**

B. Such insects are called **social insects** because different members of the colony have special jobs that help the entire colony.

C. Bees, ants, and wasps are members of an order of insects of which many kinds live in colonies as social insects.

D. Members of this order have the following characteristics.

1. Most of them have two pairs of thin, veined wings, with the front pair much larger than the back pair.
2. They have biting, sucking, or lapping mouth parts.
3. They undergo complete metamorphosis.
4. There is a definite narrowing, or constriction, between the thorax and the abdomen.

E. There are three kinds of bees in a bee colony: the **queen,** the **drones,** and the **workers.**

F. The queen is the egg-laying bee.

1. She is the largest bee in the colony, and has a long, pointed abdomen with an egg-laying organ at the tip of the last abdominal segment.
2. Her function is to lay eggs so that the colony can continue to exist.
3. She can lay both fertilized and unfertilized eggs.
4. Fertilized eggs develop into non-egg-laying females, which become the workers.
5. Unfertilized eggs develop into males, which are the drones.
6. The queen is fertilized just once by a drone (male bee), receiving several million sperm cells, which she keeps in a pouch in her body and uses the rest of her life.
7. There is usually just one queen bee to a bee colony.

G. The drones are male bees, developed from unfertilized eggs.

1. They are smaller than the queen bee, but larger than the female workers.
2. They have fat bodies, very large eyes, and powerful wings.
3. Their mouth parts are not long enough to suck up nectar so they must be fed by the workers.
4. During the summer there are usually a few hundred drones around a bee hive, but only one of them will mate with the queen.
5. In the fall, when the supply of honey is low, the workers refuse to feed the drones, and sting them to death.

H. The workers are female bees, developed from fertilized eggs.

1. They are the smallest bees in the colony, but most of the colony is made up of workers.

2. They cannot lay eggs, but they carry on all the other duties of the colony.
3. They bring in the nectar and pollen from flowers.
4. They prepare the materials that make up the hive, and they build the hive as well.
5. They prepare the food for the members of the colony.
6. Some feed the queen, others feed the drones, and still others feed the larvae that hatch from the eggs.
7. Some bees keep the hive clean, and others fan the hive to keep it airy and cool, or to help the watery nectar evaporate more quickly.

I. Workers have a "sting" at the tip of their last abdominal segment.
1. The "sting" is connected to a gland that gives off a poison, which is why a bee sting is so painful.
2. When a bee stings a person or animal, the "sting" and parts of the bee's internal organs are pulled out, and the bee dies.
3. Drones do not have a "sting."

J. Workers collect pollen and nectar from flowers.
1. Their mouth parts form a long tube, or tongue, which makes it possible for the bee to suck up nectar from the flowers.
2. The nectar is sucked into the bee's **honey stomach** or **crop**, where the nectar stays until it is brought to the hive and used as food.
3. Although pollen collects on all parts of the bee's hairy body and legs, much of it is deposited in a hairy cavity, called a **pollen basket**, located on each hind leg, and the pollen is brought back to the hive to be made into food.

K. The workers make three kinds of material for use in the hive: **wax**, **honey**, and **propolis**.

L. The wax oozes out of the segments of a worker's abdomen.
1. It usually is produced after the worker has eaten a lot of honey.
2. Other workers remove the wax that forms, chew it to make it soft, and then bring it to still other workers who use the wax to make the **honeycomb** in the hive.
3. The honeycomb is a structure in the hive that is made up of six-sided cells.
4. The honeycomb is used for storing honey and a special food, called beebread, which is made from pollen and bee saliva.
5. Eggs are also put in the honeycomb, one to a cell, by the queen, where they hatch, and the larvae are cared for by the workers.

M. Honey is made from the nectar of flowers, which the bees have collected in their honey stomachs or crops.
1. Here the sugars in the nectar are changed into honey, which is then emptied into the cells of the honeycomb.
2. The honey is watery at first, but becomes thick as the water in the honey is allowed to evaporate.
3. Workers, by fanning their wings, help the water evaporate more quickly from the honey.
4. When the honey in a cell is thick enough, the cell is sealed.

N. Propolis is a kind of bee glue.
1. It is a brown material collected from the sticky leaf buds of certain plants.
2. The workers use propolis to hold the honeycomb together, patch up holes and cracks, make the inside of the honeycomb smooth, and sometimes even to cover the body of a small, dead animal inside the hive.

O. Scientists have discovered that bees communicate with each other by doing different kinds of "dances," and in this way are able to tell other bees where they have found pollen and nectar for the colony.

P. The length of a bee's life varies.
1. Queen bees usually live for 5 or 6 years, although some have been known to live for 10 years.

2. Drones are usually killed by the workers at the end of their first season.
3. Workers live for only 3 or 4 weeks in the summer, which is the working season, but may live as long as 6 months in the fall or winter.

Q. Occasionally, during the early spring or summer, a large group of bees may **swarm**, or leave the hive, and look for a new home.
1. The bees may leave if the colony becomes too big or if food becomes scarce.
2. Sometimes they may leave if another queen is developed in the colony.
3. A queen is developed when the workers give a fertilized egg special treatment.
4. The workers make one cell of the honeycomb larger, and, when the egg hatches, the workers feed the larva a substance called **royal jelly**, which is a mixture of honey and pollen.
5. The larva is fed this royal jelly until it spins a cocoon and goes into the pupa stage.
6. When the pupa becomes an adult bee, it is a queen bee.
7. This new queen bee tries to kill the old one, but, if the workers prevent it, the new queen bee leaves the hive together with many workers and some drones.
8. After the new colony is established, the queen bee flies up into the air, and is followed by the drones.
9. One of the drones mates with the queen bee, giving her several million sperm cells, then dies soon after.
10. The queen bee then returns to the hive and lays eggs for the rest of her life.

XII. The Ant

A. Ants are also social insects.

B. They belong to the same order of insects as the bee and the wasp.

C. There are many different kinds of ants.
1. Some are quite large, and others are very small.
2. Some kinds live in tunnels in the ground.
3. Some kinds build large mounds, called anthills.
4. Some kinds live in decaying trees.

D. Ants, like bees and wasps, have a definite narrowing, or constriction, between their thorax and abdomen.

E. Ants cannot sting like bees, but they have a strong bite because of their powerful jaws.

F. An ant colony has many workers, and a much smaller number of queens and males.
1. Both the queens and males have wings, but the workers do not.
2. During the mating season the females fly high into the air, followed by the males.
3. The males mate with the females, depositing a huge number of sperm cells.
4. When the females come back to earth, they bite off their wings and start laying eggs.
5. The males die soon after they mate with the females.
6. An ant colony usually has many queens, all living peacefully together.

G. Many kinds of ants also have soldiers in their colony.
1. These soldiers do the fighting for the colony.
2. They have larger heads and powerful biting jaws.
3. These soldier ants often attack another ant colony.
4. If they defeat the other colony, they carry away the larvae and pupae of the conquered ants.
5. When these larvae and pupae become ants, these ants become slave workers for the colony.

H. All ants undergo complete metamorphosis.
1. Their eggs are tiny, and usually can only be seen under a magnifying glass or microscope.
2. Their larvae are usually white and have no legs.
3. When the larvae go into the pupa, or resting, stage, they usually spin a white cocoon.

4. These white cocoons are often mistakenly called "ant eggs."

I. The workers in an ant colony have many duties.
   1. Some workers take care of and protect the larvae and pupae.
   2. Some workers gather food for the colony.
   3. Some workers build the anthill, and others keep the colony clean.

J. Many kinds of ants keep their own "cows."
   1. These "cows" are aphids, which are also called plant lice.
   2. During the winter the ants carry these aphids into their colony and care for them.
   3. In the spring the ants set the aphids on plants, where the aphids feed.
   4. The ants then stroke the bodies of the aphids with their antennae.
   5. This stroking causes the aphids to give off a sweet liquid, which the ants drink.

XIII. Protective Coloration of Insects

A. Many insects have colors or appearances that protect them from their enemies.

B. Some insects have colors that make them look like their surroundings.
   1. The grasshopper's wings and upper parts are green and blend with the grass so that the grasshopper cannot be seen.
   2. The praying mantis has the same color as a green leaf and cannot be seen.

C. Some insects look like the object on which they are resting.
   1. The walking stick, a relative of the grasshopper, looks like a small twig.
   2. The walking-leaf butterfly looks like a large green leaf.
   3. The dead-leaf butterfly looks like a dead leaf.

D. Some insects look like other, more annoying insects.
   1. The robber fly looks like a bumble bee.
   2. The viceroy butterfly looks almost exactly like the monarch butterfly, which tastes bad to birds.

XIV. Insects Can Be Helpful and Harmful

A. Although there are more than three quarters of a million different kinds of insects on earth, most of them are neither helpful nor harmful to man.

B. Some insects are helpful to man.
   1. Many insects, such as bees, wasps, butterflies, moths, beetles, bugs, and certain kinds of flies, play an important part in the pollination of plants.
   2. Bees produce honey and beeswax.
   3. The silk moth gives us silk.
   4. The lac insect gives us shellac.
   5. The bodies of some insects, like the cochineal insect, are ground up to produce dyes.
   6. Some insects, like the dragonfly, praying mantis, and ladybug, eat harmful insects.
   7. Some insects, like the carrion beetle, are scavengers and feed on the dead bodies of animals.

C. Some insects are harmful to man.
   1. Many insects, like the grasshopper, cricket, boll weevil, and Japanese beetle, destroy grain crops, vegetables, and fruits.
   2. Some insects, especially certain kinds of moths, destroy trees.
   3. Some insects, such as the termite, destroy wooden buildings and foundations.
   4. Certain moths and beetles destroy clothes and carpets.
   5. Some insects, like the mosquito, flea, louse, and fly, carry disease germs to man and animals.
   6. Some insects, like the flea, louse, and bedbug, are parasites on man and pet animals.
   7. Some insects, like the cockroach and fly, contaminate food.
   8. Some insects, like the bee, wasp, mosquito, and gnat, annoy man and animals by stinging or biting.

D. Man uses many different methods for controlling harmful insects.

E. One method of controlling harmful insects

is to destroy the environment in which the insects live.

1. The draining of ditches and ponds, where mosquitoes breed, will break up the life cycle of the mosquitoes.
2. Changing or rotating the crops that harmful insects use for food will take away their food supply.

F. A second method of controlling harmful insects is to use quarantine laws to prevent the importing of insects into a country.

1. Sometimes the eggs or larvae of insects are brought into a country unknowingly because they are hidden on plants or fruit.
2. These insects often destroy the "balance of nature" in that country because the country has no natural enemies of the insects to hold them in check, and the insects quickly become very numerous and highly destructive.
3. Inspectors at seaports and airline terminals inspect any plants and fruit coming into the country, and take away and destroy those suspected of carrying harmful insects.

G. A third method of controlling harmful insects is to use chemicals.

1. Stomach poisons are sprayed on plants that are attacked by chewing insects.
2. Contact poisons are sprayed on plants that are attacked by sucking insects, which do not chew leaves, and these poisons kill as they come in contact with the insect's body.
3. Poison gases, which enter the insect's body through the tiny openings (spiracles) on each side of the thorax and abdomen, kill insects instantly, but the gas must be sprayed in a closed or confined area.
4. Some gases do not kill adult insects, but do destroy the larvae.
5. Many persons and scientists are very concerned about the use of chemicals to kill insects because the chemicals may enter the plants and be eaten by man, may pollute streams and kill the animal life in the streams, and may kill valuable birds, animals, and insects.
6. Also, many insects build up a resistance to chemical poisons, and their offspring inherit this resistance, making the poisons ineffective.

H. A fourth method of controlling harmful insects is to import natural enemies of the insects, or to make use of local natural enemies.

1. Birds are the best natural enemies of insects.
2. Other good natural enemies are spiders, frogs, toads, and snakes.
3. Importing a natural enemy may often become a problem because sometimes the "balance of nature" is upset, and the natural enemy becomes very numerous and equally destructive.

I. A fifth method of controlling harmful insects is to sterilize the male insects.

1. A large number of male insects are exposed to X-rays or radioactive materials.
2. This radiation makes the male insects sterile so that they cannot fertilize the female insect's eggs.
3. The sterile male flies are then released, and they mate with the female insects.
4. However, because the eggs are not fertilized by the sterile males, no new insects develop.
5. As a result, the number of harmful insects is greatly reduced, and, with repeated treatments, the harmful insects may even be wiped out completely.

SPIDERS

I. What Spiders Are

A. Spiders are members of the very large animal phylum called **Arthropoda.**

B. Together with scorpions, mites, and ticks, they form a special class of arthropods called **Arachnida.**

C. Spiders have the characteristics common to all arthropods.

1. They have an outside skeleton made of a tough material, called **chitin.**
2. The parts attached to their bodies, called **appendages,** are jointed and can bend.
3. Their bodies are segmented, and there are distinct body regions.
4. They have **bilateral symmetry,** which means that all the parts of their body are paired, being arranged on the right and left side of the body in such a way that one side of the body is a mirror image of the other side.

D. Spiders are often thought to be insects, but they are not, having special characteristics that are different from those of insects.

1. Spiders have eight legs; insects have six legs.
2. Spiders do not have antennae; most insects do have antennae.
3. The spider has its head and thorax joined together; the insect has its head and thorax separate from each other.
4. Spiders have only simple eyes, made up of just one lens; nearly all insects have compound eyes, made up of many lenses.

E. Spiders have two pairs of appendages attached to their heads.

1. One pair is hollow and has small openings in the tip, through which poison from glands in the spider's head can be injected into the spider's victim.
2. The other pair of appendages is used as feelers, and is also used by the male spider to hold sperm cells during reproduction.

F. Spiders usually have eight eyes, arranged in a definite pattern on their heads.

1. This arrangement pattern of the eyes is different for different kinds of spiders.
2. Scientists use this special arrangement pattern to classify the different kinds of spiders.

G. The respiratory or breathing organs of spiders are called **book lungs** because they have folds that look like the pages of a book.

1. Spiders usually have either two or four of these book lungs.
2. Air enters these book lungs from a slit in the spider's abdomen.

H. Many spiders have three pairs of appendages, called spinnerets, on the tip of the underside of their abdomen.

1. Each spinneret is made up of hundreds of tubes.
2. Liquid silk from the spider's silk glands flows through these tubes out into the air, where it hardens to form a thread.
3. The spider uses this thread to spin its web and to build cocoons or nests for its eggs.
4. In the fall the young of some spiders spin long threads, which are caught by the wind, and the young are carried far away.

I. Spiders do not sting, but bite instead.

1. When they bite, they inject small amounts of poison into the wound.
2. This poison is what causes the pain and swelling.

J. Spiders usually mate in the late summer or early fall.

1. The female spider is usually larger than the male, and she often eats the male after the mating has taken place.
2. The female lays a large batch of eggs, around which she spins a cocoon or nest; soon afterward some females die.
3. The eggs hatch in the winter, and stay inside the cocoon or nest.

4. The young spiders that develop usually eat each other.
5. In the spring the spiders that are still alive leave the cocoon or nest.

K. Spiders feed mostly on other insects.
1. They do not eat the insects, but suck the juices from them instead.
2. Spiders are helpful to man because many of the insects they kill are pests.

II. Some Unusual Spiders

A. The **tarantula,** or **banana spider,** is very large, and can measure as much as 6 to 8 inches across when its legs are spread.
1. It lives in the tropics, but is sometimes brought to the United States in shipments of bananas.
2. It eats insects, but sometimes it attacks small birds.
3. Its bite is painful, but does not cause death.

B. The **black widow spider** is found mostly in warm climates, but can occasionally be seen in temperate climates.
1. It has a round, black abdomen, with a red spot, shaped like an hour glass, on the underside of its abdomen.
2. The female is vicious, and kills the male after she has mated with him.
3. The black widow's bite is very painful and poisonous, and sometimes can cause death.
4. The black widow's thread is so fine that it has been used in marking the lenses of gunsights, bombsights, and surveying instruments.

C. **Trapdoor spiders** are unusual spiders found in the southeastern part of the United States.
1. Instead of spinning webs to catch insects, they build a kind of trapdoor.
2. They dig a tubelike hole in the ground, line it with silk, and fasten a hinged "door" over the hole.
3. The door is kept open until an insect comes into the hole, and then the door is shut tight.

III. Relatives of Spiders

A. The **scorpion** is an arachnid found in all tropical countries and in southern and southwestern United States.
1. In addition to its four pairs of walking legs, it has a large pair of appendages attached to its head, with a large pincer at the end of each appendage.
2. It has a long, segmented abdomen that forms a tail at the end.
3. At the tip of the tail is a poisonous stinger, which the scorpion uses to kill insects and spiders.
4. The scorpion's sting is very painful, but it rarely is fatal to man.

B. The **harvestman,** or **daddy longlegs,** looks very much like a long-legged spider.
1. It is one of the most useful arachnids to gardeners because it feeds mostly on plant lice.
2. It is usually found in gardens, fields, and woods.

C. **Mites** and **ticks** are very small arachnids that look like lice.
1. They live mostly as parasites on the bodies of man, chickens, cattle, dogs, and other animals.
2. They are dangerous because they carry disease germs from one animal to another.
3. Mites carry such diseases as sheep scab and dog mange.
4. Ticks carry such diseases as Rocky Mountain spotted fever and Texas cattle fever.
5. **Chiggers** are mites that bore into the skin of humans, causing itchiness and pain.
6. The "red" spider that harms apple leaves and fruit is really a mite.

FISH

I. What Fish Are

A. Fish are members of the animal phylum called **Chordata.**

B. Together with amphibians, reptiles, birds, and mammals, they make up a special group of animals called **vertebrates.**

C. Most vertebrates have the following characteristics.

1. They have backbones.
2. Their skeletons are inside their bodies.
3. They usually have two pairs of limbs, or appendages (legs, legs and wings, or fins), attached to their bodies at the shoulder and hip.

D. Fish are grouped into three broad classes: the **bony fish,** the **lampreys,** and the **sharks and rays.**

1. The skeletons of the bony fish are made of bone, but the skeletons of the other two groups of fish are made of a tough tissue, called **cartilage.**
2. The bony fish make up the most important group, both on the basis of numbers and of economic importance.

II. Where They Are Found

A. Fish live only in water.

1. Most fish are found in the ocean, but there are also many fish in lakes, ponds, rivers, and brooks.
2. Some fish live near the surface of the water, and others live closer to the bottom.

B. Some fish live alone whereas others travel in large groups, called **schools.**

C. Although some fish are less than 1 inch long and others are as much as 50 feet long, most fish are less than 3 feet long.

III. Physical Characteristics

A. There are three parts to the body of a fish: a head, trunk, and tail.

1. The head has no neck and is attached directly to the trunk.
2. The trunk is the largest part of the body.
3. The tail is the narrower part of the body behind the trunk, and is often confused with the tail fin.

B. The body of a fish is streamlined and tapers at both ends.

C. The bodies of most fish are covered with scales, which grow from pockets in the skin and overlap one another just like the shingles on the roof of a house.

D. The skin of a fish gives off a slime, which oozes between the scales and covers the body.

1. This slime makes it easier for the fish to swim.
2. The slime also protects the fish from being attacked by tiny parasites in the water.

E. Some fish are brightly colored, either partially or completely, with the colors often arranged in spots, lines, or bars.

F. Many fish are dark colored on top and light colored underneath, which helps prevent them from being seen by their enemies.

G. Most fish have eyes that are large and slightly movable.

1. The pupil of the eye is large, as compared with other vertebrates, and can admit a great deal of light.
2. A fish has no eyelids.

H. The trunk of a fish has a number of appendages, called **fins.**

1. Each fin is made up of many bony spines, called **rays,** which are covered by a thin fold of skin.
2. A pair of fins, called the **pectoral fins,** is located near the head, and corresponds to the front legs of land vertebrates.
3. In back of the pectoral fins is a second pair of fins, called the **pelvic fins,** which corresponds to the rear legs of land vertebrates.

4. Along the top of the trunk there can be found one or two **dorsal fins.**
5. Along the bottom of the trunk, toward the rear, there is an **anal fin.**

I. The tail of a fish ends in a fin, called the tail fin or **caudal fin.**

J. Fish are called **cold-blooded** animals because the temperature of their blood is the same as that of the surrounding water, and this temperature changes with the seasons.

IV. How Fish Breathe

A. Fish breathe through respiratory organs, called **gills,** located on each side of the head.
1. The gills are made up of many small, threadlike filaments, which give the gills a feathery appearance.
2. Each filament has tiny, thin-walled blood vessels in it.

B. Most fish breathe by opening and closing their mouths.
1. When a fish opens its mouth, water rushes in.
2. When the fish closes its mouth, the water is forced out through two openings on each side of the back of the head.
3. There are four or five gills in each opening.
4. As the water is forced out over the gills, dissolved oxygen in the water passes through the thin walls of the blood vessels and is picked up by the blood.
5. The blood gets rid of its carbon dioxide as it picks up fresh oxygen.

V. How Fish Swim

A. A fish swims forward rapidly by moving its tail and tail fin from side to side.

B. The dorsal and anal fins are used mostly for balance, and help keep the fish from tipping over.

C. The paired pectoral and anal fins have several functions.
1. They help a fish keep its balance when the fish is resting.
2. They act as oars when the fish is swimming slowly.
3. They help the fish steer to the right or left.
4. When spread out at right angles, they act as brakes to help the fish come to a stop.
5. The fish also uses them to swim backward.

D. Most fish have an **air bladder** inside their bodies.
1. Gases from the body can enter or leave the air bladder, making it inflate or deflate.
2. The air bladder makes it possible for the fish to rise, sink, or stay at a particular depth without rising or sinking.

VI. What Fish Eat

A. Some fish eat only algae and other water plants.

B. Some fish eat animals, such as insects, worms, crayfish, snails, and other fish.

C. Fish that eat other animals have many sharp teeth.
1. These teeth slant backward toward the throat, making it easy for a fish to swallow the animal, but making it hard for the animal to escape.
2. Fish can use their teeth to seize, tear, and hold food, but cannot use them for chewing.

VII. How Fish Reproduce

A. Most fish develop from eggs that the female lays outside her body.

B. At a certain time of the year a female fish lays a very large number of eggs.

C. This process of laying eggs is called **spawning.**

D. Shortly after the female lays her eggs, the male swims over the eggs and gives off a liquid, called **milt,** which contains large numbers of sperm cells.

E. The sperm cells swim to the eggs and fertilize the eggs by uniting with them.

F. The fertilized eggs hatch into tiny fish, usually from 10 to 40 days later, depending on the kind of fish and the temperature of the water.
   1. While the fish are developing from the egg, they are fed by the yolk of the egg.
   2. A part of the yolk, called the yolk sac, remains attached to the newborn fish for some time after they hatch, and supplies them with the food they need during this time.

G. The young of some freshwater tropical fish, like the guppy, molly, and swordtail, develop inside the female's body and are born alive.
   1. The female keeps her eggs inside her body and receives the sperm of the male when he mates with her.
   2. The sperm fertilize the eggs, which develop inside the female's body and then are brought forth alive.

H. As a rule, most freshwater fish either spawn where they live or travel a short distance to shallower water for spawning.

I. The eel, however, has a very unusual spawning habit.
   1. The eel lives in rivers and streams that flow into the ocean.
   2. At spawning time the eels that live in rivers flowing into the Atlantic Ocean and Gulf of Mexico swim far out into the Atlantic Ocean.
   3. The female lays her eggs and the male deposits his sperm on the eggs; then both male and female eels die.
   4. When the young eels that hatch from the fertilized eggs are about 2 inches long, they return to the rivers and streams from which their parents came.
   5. After 3 to 8 years the adult eels return again to the same part of the Atlantic Ocean for spawning.
   6. Although both American and European eels spawn in the same part of the Atlantic Ocean, the young eels never make a mistake and go to the wrong continent.

J. The Pacific salmon also has unusual spawning habits.
   1. The adult fish live in the ocean along the north Pacific coast.
   2. At spawning time they all swim up the Columbia River to the same streams where they had hatched 3 or 4 years earlier.
   3. The females spawn and the males deposit their sperm, fertilizing the eggs; then both males and females die.
   4. The young salmon that hatch from the eggs then return to the ocean and live there for 3 or 4 years until it is time for them to spawn.

VIII. The Economic Importance of Fish

A. Fish are very valuable to man as food.
   1. Common saltwater food fish include the tuna, herring, sardine, swordfish, halibut, mackerel, haddock, sole, flounder, cod, and sea perch.
   2. Common freshwater food fish include the trout, salmon, pike, whitefish, perch, buffalo carp, and catfish.

B. Many persons catch fish for sport and recreation, as well as for food.

C. The eggs of the sturgeon, commonly called "caviar," and the shad are eaten as food.

D. The oil from the liver of the codfish, halibut, and shark is rich in vitamins A and D.

E. Fish oil is used in making certain paints.

F. Ground fish, called fish meal, is used in making foods for cats, dogs, and chickens.

G. The bones and waste parts of fish are used to make glue.

IX. The Conservation of Fish

A. Many lakes, ponds, and streams lose their fish for many reasons.
   1. Lakes may become lower during hot, dry spells or because of unwise treatment of the land around the lake, and this lowering of the water level may destroy spawning areas or areas where the food supply is rich.
   2. Sometimes man straightens river channels, which discourages the breeding of

fish because fish live better in rivers that have bends, rapids, and quiet pools.

3. Dams across rivers stop fish from traveling upstream to spawn.
4. Many lakes and streams are contaminated by sewage and chemical wastes, which can poison and kill the fish.
5. Sometimes too many adult fish are caught during the spawning season, or too many young fish are caught before they can become adult and have the opportunity to breed new fish.

B. To protect and conserve the fish, the states have passed many protective laws with the following restrictions.

1. Fish under a certain length must not be kept, but must be thrown back.
2. Only a certain number of fish may be caught in one day.
3. Certain fish may not be caught during their spawning season.
4. Fish must not be caught by using explosives in the water.
5. Sewage and chemical wastes cannot be dumped in certain lakes and streams that have been set aside for fishing.
6. Dams that interfere with the travel of fish upstream to spawn must have beside them **fish ladders**, which are a series of small pools, one higher than the other, connected by small waterfalls that can be leaped by the fish.

C. Both the federal government and the states have established fish hatcheries to breed and raise fish for lakes and streams.

1. In the hatchery the eggs are taken from the female and put into a tank, and then milt, containing the sperm of the male, is poured over the eggs.
2. In this way almost all the eggs are fertilized, and hatch.
3. When the young fish are old enough to take care of themselves, they are taken to the lakes and streams.

D. Scientists are constantly investigating diseases, fungus infections, and natural enemies of fish, in an effort to keep the balance in nature constant.

X. Relatives of the Bony Fish

A. The **lamprey** is a very simple or primitive kind of fish.

1. Some kinds of lampreys live in saltwater, and other kinds live in freshwater.
2. The lamprey has a long, thin body and looks very much like an eel.
3. Its skeleton is made of cartilage instead of bone.
4. It has a soft, slimy skin.
5. The only fins it has are two fins along its back and a tail fin.
6. It has no jaws at all, but it has a round, sucking mouth lined with sharp teeth.
7. Its tongue is hard and rough, with teeth on it, so that it can act like a coarse file.
8. The lamprey is a parasite, living on the blood of other fish.
9. Its sucking mouth clamps onto the side of a fish, and it uses its teeth and tongue to rip through the scales and flesh of the fish.
10. The lamprey then sucks out the blood, and sometimes even the internal organs, of the fish.

B. Although the **shark** is very much like a bony fish, it has certain characteristics that place it in its own group or class.

1. Sharks live only in saltwater.
2. Some sharks are about 2 feet long, but others can be 50 feet long or more.
3. The shark's skeleton is made of cartilage instead of bone.
4. A shark's scales do not overlap, like those of the bony fish, but instead lie side by side.
5. Its fins are very much like those of a bony fish, but the upper part of its tail fin is longer than the lower part.
6. Its mouth is on the lower side of its head, and is lined with many rows of very sharp teeth.
7. Sharks live on other fish.

C. The **ray** belongs to the same group of fish as the shark.

1. The ray is also called the **devilfish**, **sting ray**, or **blanket fish**.

2. It has a large, flat body that looks like a blanket.
3. When it swims, the sides of its body look somewhat like moving wings.
4. It has a long, whiplike tail with a sharp, poisonous stinger on the tip.
5. It uses this stinger to wound and kill the fish and other sea animals that it attacks and eats.
6. The ray lives only in saltwater, and often lies half-buried in the sand, looking somewhat like a blanket.

AMPHIBIANS

I. What Amphibians Are

A. Amphibians are members of the animal phylum called **Chordata.**

B. Together with fish, reptiles, birds, and mammals, they make up a special group of animals called **vertebrates.**

C. As vertebrates, amphibians have the following general characteristics.
1. They have backbones.
2. Their skeletons are inside their bodies.
3. They have two pairs of appendages attached to their bodies at the shoulder and hip.

D. Amphibians also have their own special characteristics.
1. Their bodies are covered with a thin, loose skin that is usually moist.
2. Their feet are often webbed, and they have no claws on their toes.
3. Their eggs are fertilized outside the female's body.
4. Young amphibians live in the water, but adult amphibians live mostly on land (the term *amphibia* means "two lives").
5. Young amphibians look different from adult amphibians, which means that a change, or **metamorphosis,** takes place when the young amphibian becomes an adult.
6. They are cold-blooded, and their body temperature is always the same as that of the air or water around them.

E. Common amphibians include frogs, toads, and salamanders.
1. They are all rather small vertebrates.
2. Most frogs and toads are from 2 to 5 inches long, although the African frog is about 1 foot long.
3. Salamanders usually are from 2 inches to 2 feet long, and there is a giant salamander in Japan that is 5 feet long.

II. The Frog

A. The frog has a short, broad body.
1. The body is covered by a thin, loose, moist skin that is colored very much like the surroundings the frog lives in.
2. Glands in the skin give off a slimy mucus, which makes the skin slippery.

B. The frog has large bulging eyes, which have upper and lower eyelids.
1. There is also a third eyelid, called the **nictitating membrane,** joined to the lower eyelid.
2. This extra eyelid protects the eye when the frog is under water and keeps the eye moist when the frog is on land.

C. The frog has a very large mouth with a long, sticky tongue attached to the bottom in front.
1. When a frog catches an insect, the mouth opens up wide and the tongue shoots out.
2. The insect is caught on the sticky tongue, which throws the insect against the roof of the mouth.
3. The frog then closes its mouth quickly and swallows the insect.

D. The frog has two short, weak front legs.
1. Each leg has four toes.

2. The front legs are used to support the frog and to break the force of the frog's fall after it has made a leap.

E. The frog has two highly developed rear legs, which are used for swimming and leaping.
   1. Each leg has five long toes with webbing between them.
   2. When the frog is resting on land, the rear legs fold together along the body in a position that makes it possible for the frog to make a quick leap at any time.

F. On land the adult frog breathes through its lungs.

G. In the water the frog breathes through its skin.
   1. Oxygen dissolved in the water passes directly through the skin into the blood while carbon dioxide leaves the blood and passes out through the skin.
   2. This breathing through the skin makes it possible for the frog to stay under water or bury itself in the mud for long periods of time.

H. In the early part of spring the female frogs lay their eggs in ponds.
   1. The eggs are surrounded by a jellylike material that holds them together.
   2. As the eggs pass out of the female, the male immediately spreads sperm over them.
   3. The sperm enter the eggs and fertilize them.

I. The eggs of a frog are black and white.
   1. The white part is the yolk, which contains stored food for the young frog when it first hatches from the egg.
   2. The black part is the living protoplasm, which will produce the young frog.

J. The young frog that hatches from the egg is called a **tadpole.**
   1. At first the tadpole is a tiny animal with a short body.
   2. It immediately attaches itself to water plants and feeds on the yolk part of the egg and also on the jellylike material that surrounded the egg.
   3. A mouth and horny jaws soon develop, and the tadpole begins to feed on tiny plants.
   4. The body begins to lengthen, gills form at the sides of the head, and the tail becomes longer.
   5. The tadpole is now a fishlike animal and swims about freely in the water.

K. The tadpole eventually grows into an adult frog and lives on land.
   1. First the hind legs appear, and then the front legs form.
   2. As the legs develop, the tail is absorbed or taken into the body and disappears.
   3. Changes take place inside the body, and lungs form.
   4. The tadpole is now completely changed, or has undergone **metamorphosis,** into a frog.

L. Frogs are **cold-blooded** animals, which means that their body temperature is always the same as the surrounding air or water.
   1. When winter comes the body temperature of the frog becomes so low that the frog cannot be active any more.
   2. The frog buries itself in the mud at the bottom of a pond and stays quiet or inactive all winter.
   3. This period of winter inactivity is called **hibernation.**
   4. In the spring the days become warmer, and the frog becomes active again.
   5. When it is very hot in the summer the frog may bury itself again in the cool mud and become inactive once more.
   6. This period of summer inactivity is called **estivation.**

M. The **leopard frog** is the most common frog in the United States.
   1. It lives in damp places near ponds, marshes, and ditches.
   2. Its back is covered with dark spots surrounded by white or yellow rings, and it looks very much like the grass and rocks among which it lives.
   3. Its underside is a creamy white.
   4. The tadpoles of leopard frogs become adults in a single summer.

5. The leopard frog lives on insects, worms, and crayfish.
6. The leopard frog is often used by fishermen as bait, and it is also used for dissection in the laboratory.

N. The **bullfrog** lives mostly in water.
1. It is a large frog with legs that may be as much as 10 inches long.
2. Most bullfrogs are a greenish-brown, although their color may range from green to yellow.
3. Their undersides are a greyish-white mixed with dark splotches.
4. It takes two summers for the tadpole of a bullfrog to become an adult.
5. Bullfrogs feed on insects, worms, crayfish, and small fish.
6. The large legs of the bullfrog are eaten as food.

O. The **tree frog** is a very small frog, no more than an inch long, that climbs trees.
1. Its body looks very much like the bark of a tree.
2. Its toes have sticky pads on them that make it possible for it to climb trees easily.
3. It makes a very loud noise for its size.

III. The Toad

A. The toad is very much like the frog in many ways.
B. However, the frog's skin is moist and slippery, whereas the toad's skin is dry and covered with warts.
C. The toad has shorter legs than the frog.
D. The toad lives on land all the time, and returns to the water only to lay eggs.
E. The life cycle of the toad is very similar to that of the frog.
1. However, the toad's eggs are laid in strings instead of masses like the frog's eggs.
2. Also, the tadpole stage is very short, and the tadpoles become toads very quickly.

F. The toad has no teeth, but the frog does have teeth.
G. The toad cannot swim in water.
H. The rounded warts on its back, sides, and legs have poison glands, which help protect the toad from some of its enemies.
I. The toad sleeps most of the day under rocks and logs, and becomes active at night.
J. It feeds on insects and slugs that destroy garden plants.

IV. The Salamander

A. The salamander looks more like a lizard than a frog or toad.
1. It has a long body, long tail, and short legs, all about the same size.
2. Its skin is soft and moist, and its legs have no claws.
3. Some salamanders do not have legs at all.

B. Some salamanders live in water, and others live on land in damp places.
C. The **mudpuppy** or **necturus**, which is common in the Midwest, has a pair of red gills around its head just above its front legs, and keeps these gills all its life.
D. The **tiger salamander** has yellow bars on a brown body, whereas the spotted **salamander** has yellow spots on a black body.
1. The tiger salamander has a flat tail, and the spotted salamander has a round tail.
2. They both live in water the first three months of their lives, then on land the rest of the time.

E. The **newt** is a salamander that has a "triple life."
1. The first two months of its life it lives in the water and breathes only through its gills.
2. The next year or two it lives on land and breathes through lungs.
3. Then it goes back to the water for the rest of its life, breathing through its lungs on the surface of the water and through its skin when under water.

REPTILES

I. What Reptiles Are

A. Reptiles are members of the animal phylum called **Chordata.**

B. Together with fish, amphibians, birds, and mammals, they make up a special group of animals called **vertebrates.**

C. As vertebrates, reptiles have a backbone, their skeletons are inside their bodies, and most of them have two pairs of appendages attached to their bodies at the shoulder and hip.

D. Reptiles also have their own special characteristics.

1. They have a thick, dry skin covered with scales.
2. Those reptiles with feet have claws on their toes.
3. Both young and adult reptiles breathe only through lungs.
4. Reptiles have a breastbone, called the **sternum,** which protects the heart and lungs.
5. The female's eggs are fertilized by the male's sperm inside her body.
6. The eggs that are laid have a protective shell or membrane around them.
7. Reptiles are **cold-blooded,** which means that their body temperature is always the same as that of the air or water about them.

E. At one time the reptiles were the most numerous and most powerful animals on earth.

F. Today there are only a few different kinds of reptiles that exist.

G. Common reptiles include the turtle, lizard, snake, alligator, and crocodile.

II. The Turtle

A. Some turtles live in salt water, others live in fresh water, and still others live on land.

1. Land turtles are often called **tortoises.**
2. Some kinds of freshwater turtles are also called **terrapins.**

B. Some turtles are quite small, but others, especially the sea turtles, can be 8 feet long and weigh 1000 pounds.

C. All turtles have an upper and lower shell with the body between these shells.

1. The shells protect the turtle because most turtles can withdraw all of their body parts into the shells.
2. Some turtles can even close their shells tightly.
3. The shells have plates that are different in color and marking, and this difference helps biologists identify all the kinds of turtles.

D. A turtle has either a pointed or triangular head.

E. It has no teeth, but it does have horny jaws that form a sharp beak, which the turtle uses to bite off pieces of food.

F. It has well-developed eyes and good eyesight.

1. The eyes have an upper and a lower eyelid.
2. There is also a third eyelid, called the **nictitating membrane,** which is transparent and moves from the front corner of the eye to cover the eyeball.

G. The turtle's legs are quite short, and the turtle walks very slowly.

1. The skin on a turtle's legs is scaly and tough.
2. Most turtles have five toes on each leg, and the toes have claws on them.
3. Some turtles have completely webbed toes, but others have very little webbing between the toes.
4. Water turtles use their webbed feet for swimming.

H. Some turtles have good-sized tails, but others have little or no tails.

I. All turtles, even sea turtles, lay their eggs on land.

1. They lay their eggs in shallow holes and cover them with sand or earth.
2. The heat of the sun helps the eggs hatch.

J. Land turtles eat insects, earthworms, and different kinds of plants; water turtles eat fish, frogs, and birds that live near the water.

III. The Lizard

A. Most lizards live in the tropics.

B. Some lizards, like the **skink** or **swift**, are very tiny, but the **Komodo dragon lizard** of the Dutch East Indies is 15 feet long and weighs almost 250 pounds.

C. Most lizards have four legs, and some lizards can run very quickly.

D. A few lizards, like the **glass snake**, have no legs and are often mistaken for snakes.

E. The **chameleon** is the best-known lizard in the United States.
1. It has a body that is about 2 inches long and a tail about 3 inches long.
2. The chameleon can change its color, not just once but many times.

F. The **horned toad** is really a lizard, and it can be found in western United States.
1. It has scales of different lengths, which give it a horny appearance.
2. Some horned toads lay their eggs, but others keep the eggs inside their bodies and the young are born alive.

G. The **Gila monster** is a poisonous lizard 2 feet long, found in Arizona and New Mexico.
1. Its skin is brown or black and is covered with blotches of orange or pink.
2. It has poison glands at the rear of its lower jaw.
3. It bites very hard, twisting its head from side to side.
4. Its poison affects the heart and can often kill a man.

H. The **iguana**, a lizard that lives in the tropics, looks like a dragon.

I. Some lizards, like the glass snake, can have their tails broken off and will still grow new ones.

IV. The Snake

A. Many biologists believe that snakes developed from lizards a long time ago.

B. Snakes have long, round bodies that are covered with scales, many of which are beautifully colored.

C. Snakes shed their outer layer of scales many times during a single season.
1. This process is called **molting**.
2. When the thin layer becomes loose, the snake hooks a loose part over a twig or stone edge, and then works its way out of this old layer of "skin."

D. The snake has no legs, and moves by using the broad scales, called **scutes**, on the underside of its body and by using a large number of muscles.
1. Snakes commonly move by winding from side to side and forming curves.
2. Some snakes move up and down slowly in a straight line, like a caterpillar.
3. Some snakes that live in the desert have a side-winding movement, where the body is raised and twisted into S-shaped loops, touching the ground only at two or three points, with the snake moving across the ground only at these points.
4. Most snakes move quite slowly, and even the fastest snakes cannot travel faster than 3 miles an hour.

E. The snake has a large mouth with a double row of teeth on each side of its upper jaw and a single row of teeth on its lower jaw.
1. The teeth all slant backward toward the throat.
2. The snake swallows its food whole, and uses its teeth only to hold and pull the food while it is swallowing.
3. The snake's jaws are flexible and can stretch very much, so that the snake can even swallow animals thicker than its own body.
4. There is a long, forked tongue in the snake's mouth, which the snake thrusts out and uses for smelling.

F. The snake has no eyelids, which makes it different from other reptiles.

1. There is a transparent scale, however, that covers the eye.
2. Some snakes have round eye pupils, and others have oval or elliptical eye pupils.

G. All snakes eat only animals, and they use different methods for getting their food.

H. Most snakes just grab the animal by their mouths and swallow it alive.

1. These snakes eat insects, frogs, toads, lizards, rats, mice, squirrels, and other small animals.
2. Examples of snakes that use this method of getting food include the **garter snake, hog-nosed snake,** and **milk snake.**

I. Some snakes first wrap their bodies around an animal's chest and squeeze hard so that the animal cannot breathe and dies.

1. Usually these snakes are quite long and have fairly thick bodies.
2. Examples of snakes that kill by this squeezing method include the **boa, python, king snake,** and **bull snake.**
3. The king snake eats other snakes, even the poisonous ones.

J. Some snakes first poison the animal quickly, and then swallow it after it dies.

1. These snakes have poison fangs in their mouths.
2. These fangs are hollow, and, when the snake strikes the animal with these fangs, poison from poison glands flows through the fangs into the animal and kills it.
3. Examples of snakes that kill by poisoning include the **rattlesnake, water moccasin, copperhead, coral snake,** and **cobra.**

K. Most snakes lay eggs that have a tough, white shell.

1. Each egg has stored food in it for the young snake that is developing inside.
2. The heat of the sun helps the egg hatch.

L. A few snakes, like the garter snake and copperhead, keep the eggs inside their bodies and the young snakes are born alive.

V. The Alligator and the Crocodile

A. The alligator and crocodile are large reptiles that live mostly in tropical and semitropical climates.

1. Alligators are found mostly in the southern United States.
2. Crocodiles are found largely in Africa and India, but there are also some crocodiles in the southern United States and in South America.

B. They are covered with large, bony scales, and their legs have toes that are partly webbed.

C. Most of them live in swamps and along the banks of a river.

D. The crocodile spends more time in the water than the alligator does.

E. Both the alligator and the crocodile look alike, but there are definite differences between them.

1. The crocodile has a narrower and more triangular head, and its snout is more pointed.
2. The alligator is a brown color, whereas the crocodile is a kind of grayish-green color.
3. The alligator is rather sluggish, whereas the crocodile is more active.

F. The alligator and crocodile will eat fish and any land animals that may come near them.

1. Some alligators and crocodiles eat man.
2. The crocodile, especially the African crocodile, is more likely to attack man than the alligator.

G. Alligator hide is used to make fine shoes, handbags, and luggage.

BIRDS

I. Characteristics of Birds

A. Birds are members of the animal phylum called **Chordata.**

B. Together with fish, amphibians, reptiles, and mammals, they make up a special group of animals called **vertebrates.**

C. As vertebrates, birds have the following general characteristics.
1. They have backbones.
2. Their skeletons are inside their bodies.
3. They have two pairs of limbs, or appendages, attached to their bodies at the shoulder and hip.

D. Birds also have their own special characteristics.
1. Their bodies are covered with feathers.
2. They have a very light, compact skeleton with porous or hollow bones filled with air, and this kind of skeleton makes it easier for birds to fly.
3. Instead of front legs, birds have wings, which they use only for flying.
4. They stand and perch on two legs.
5. They have a horny beak and no teeth in their mouths.
6. The female's eggs are fertilized by the male's sperm inside her body.
7. The females lay eggs that have a protective shell.
8. Birds are **warm-blooded,** which means that their body temperature is always the same, regardless of the temperature of the air about them.

E. Birds are all different sizes.
1. The smallest bird is the hummingbird, which is a little more than 2 inches long and weighs about $\frac{1}{10}$ ounce.
2. The largest bird is the ostrich, which can be as much as 7 feet tall and weigh more than 250 pounds.

F. The feathers of birds are really scales, whose form has been changed.
1. The feathers grow from little pits in the skin.
2. They grow only on certain parts of the skin, but they spread out to cover those parts that are featherless.

G. There are four kinds of feathers.
1. The soft **down feathers,** which are plainly seen on young birds, are close to the skin and help keep both young and adult birds warm.
2. The **filoplumes** are thin, almost hairlike feathers with a tuft on their ends.
3. The **contour feathers** cover and protect the body and also give the bird its characteristic color.
4. The large, strong **quill feathers** are in the wings and tails, and are used mostly for flying.

H. Baby birds have mostly down feathers, which makes them look slightly different from their parents.

I. As the baby birds become older, they grow the other kinds of feathers and begin to look more like their parents.

J. The feathers of birds are widely different in color.
1. Some kinds of birds have males that are brilliantly colored and females with little color.
2. In other kinds of birds both the males and females are colored the same.
3. Usually, young birds are colored a little differently from adults.

K. Birds shed, or **molt,** their feathers at least once a year, and new feathers replace those that have either fallen out or been broken.

L. Birds have large eyes that not only give them sharp eyesight, but also make it possible for them to judge distances very well.

M. Birds also possess a very keen sense of hearing.

N. Most birds have a small, horny tongue, which they use to touch things.

O. Most birds have a voice, and some birds can sing beautifully.

II. Where Birds Live

A. Birds live in all parts of the world, from the polar regions to the tropics.
B. All kinds of birds live in the woodlands and in the open fields.
C. Many kinds of birds live near oceans, lakes, swamps, and marshes.
D. Some birds, like the pigeon and starling, live in the city.
E. Many birds **migrate**, or move from one home to another, during the spring and fall of the year.
  1. Scientists offer different reasons to explain why birds migrate.
  2. Birds may migrate because the climate changes, because their food supply is gone, or because they are accustomed to breed in certain parts of the world.
  3. Most birds that live in the north fly south for the winter.
  4. The bobolink spends its winter in Argentina, the wood thrush in southern Mexico, and the house wren in Florida.
  5. Some birds make very long migration flights.
  6. The golden plover summers in northern Canada and winters in Brazil and Argentina.
  7. The arctic tern summers in the Arctic regions and winters in the Antarctic regions.
  8. The ruddy turnstone summers in Alaska and winters in Hawaii.

III. What Birds Eat

A. Birds are so active that they need large amounts of food, and they seem to be eating all the time.
B. The two main foods of birds are insects and seeds.
C. Some birds, like the crow, bluejay, and red-winged blackbird, also eat corn, grain, rice, and peas.
D. Some birds, like the bluebird, robin, cedar waxwing, and wren, also eat fruit and berries.
E. Some large birds, like the owl and hawk, eat small animals, such as the rat, field mouse, and rabbit.
F. Some birds, like the pelican, kingfisher, and loon, eat mostly fish.
G. Some birds, like the vulture and buzzard, eat dead animals.
H. Most birds drink by taking a beakful of water, tilting their heads back, and letting the water run down their throats.

IV. How Birds Reproduce

A. When birds mate, the male deposits sperm inside the female so that the female's egg cells are fertilized internally.
B. Soon after, the female lays a number of eggs with hard shells around them.
  1. Each egg has a tiny fertilized egg cell in it.
  2. The egg also contains yolk, a substance which serves as stored-up food while the young bird is gradually developing inside the egg.
  3. Some birds, like the owl and hawk, may lay just one egg, but other birds, like the chicken, duck, goose, and turkey, may lay 20 or more eggs at one time.
C. As soon as the female bird lays her eggs, she sits on them to keep them warm so that the eggs will develop into birds.
  1. This process of sitting on the eggs and keeping them warm until they hatch is called **incubation.**
  2. The time needed to incubate the eggs varies from about 10 days for smaller birds to as much as 50 days for larger birds.
  3. Usually the female sits on the eggs while the male gets food.
  4. For some birds, like the ostrich, the male bird will take turns with the female bird in sitting on the eggs.
D. When the egg is ready to hatch, the baby bird pecks the shell until it splits open, and then the baby bird works its way out of the shell.
E. Baby birds, like the robin and cardinal,

which hatch in 10 days to 2 weeks, are quite helpless.

1. They are weak, almost blind, and covered with very few down feathers.
2. They must be fed and cared for many days before they become feathered, are able to fly, and can get food for themselves.

F. Baby birds, like the chicken and the quail, which hatch in 3 to 6 weeks, are well formed and can run around and look for food within a few hours after they have hatched.

V. The Nesting Habits of Birds

A. Birds build nests to provide a place for incubating and hatching their eggs and for protecting the young birds when they are newly born.

B. Birds choose sites for their nests where they can get the greatest protection possible from their enemies and from such weather conditions as heavy rains or strong winds.

C. Nests differ greatly in size and shape, in the materials used to make them, and in how well they are made.

1. Different kinds of birds build their nests in their own way, with the same kinds of materials, and in the same kind of location.
2. Some birds build large nests, and the materials are put together very loosely.
3. Other birds build small nests that are beautifully constructed with different materials, and the nests are then lined with soft materials.
4. Birds use such materials as earth, clay, twigs, grass, stems, leaves, bark, hair, feathers, and even string to build their nests.

D. Shore birds, like the penguin and the arctic tern, lay their eggs on rocks or pebbles that have been arranged on the ground in such a way as to keep the eggs from rolling.

E. The whippoorwill lays its eggs on dead leaves in a small hole in the ground.

F. The kingfisher lays its eggs in a hole that has been dug in a clay bank, and the eggs rest either on the bare ground or on feathers.

G. The duck builds a very simple grass nest.

H. The oriole builds a long, baglike nest, made of grass, string, and hair, on the branch of a tree.

I. The owl and woodpecker live in holes that have been cut out of hollow or dead trees.

J. The bluejay builds a bulky, rough nest on a tree branch, and the nest is made of twigs, leaves, grass, and string.

K. The robin builds a heavy, bulky nest on a tree branch or in the crotch of a tree, and the nest is made of twigs and mud, and then lined with grass.

L. The meadowlark and quail build grassy nests in underbrush.

M. The barn swallow builds its nest in hollow trees or in the eaves of a house, using straw and mud, and it lines the nest with hay or feathers.

N. The hummingbird builds a tiny, basketlike nest on the high branches of a tree.

O. Some hawks and eagles build their nests in very tall trees.

P. Screech owls often build their nests in barns.

VI. Birds Have Different Beaks, Feet, Wings, and Tails

A. The feet, beaks, wings, and tails of birds are different in form and structure so that they are fitted for special functions, such as perching, swimming, catching food, eating, and flying.

B. These special forms, structures, and functions are called **adaptations.**

C. Birds have different kinds of feet, depending upon whether they are fitted or adapted for perching, climbing, swimming, wading, or grasping.

1. Seed-eating birds, like the robin and bluebird, have three toes in front and

one behind, which are used for perching on branches.
2. Birds, like the duck and the goose, have long, webbed toes for swimming.
3. Birds, like the crane and the heron, have long legs and separate toes for wading.
4. Birds, like the duck and the loon, have short legs set far back for diving.
5. Birds, like the woodpecker, have two toes in front and two toes in back, and this arrangement helps them when climbing tree trunks.
6. Birds, like the owl, hawk, and eagle, have powerful claws, called **talons**, on their toes, which are used for grabbing and holding small animals.

D. Birds have beaks that are specially fitted or adapted for gathering their food and eating.
1. The duck has a wide, flat, and notched beak, which is used for scooping up and straining food.
2. The owl, hawk, and eagle have their upper jaw curved over the lower jaw, making the beak hooked, so that it is easy to tear flesh.
3. The heron and snipe have a long, pointed beak for searching food in the mud.
4. The sparrow and finch have a short, straight, stout beak for crushing seeds and other hard foods.
5. The hummingbird has a long, thin beak, which is curved in some cases, for reaching into the bottoms of deep flowers and obtaining nectar.

E. The shape of the bird's wing is fitted or adapted for the kind of flying that a bird does.
1. Soaring birds, like the hawk, have long, broad wings.
2. Sailing or gliding birds, like the gull, have long, slender wings.
3. Birds that maneuver quickly, like the robin, have short, broad wings.
4. Ground birds, like the pheasant and the partridge have short wings that can furnish only short, quick flights.
5. Chickens do not fly much, and have underdeveloped wings.
6. The penguin has wings that are paddle-shaped for swimming.

F. The bird's tail acts as a rudder in flying and as a balance in perching.
1. The woodpecker has a stiff tail, which supports the woodpecker when it is climbing a tree trunk.
2. The bluejay has a long tail for balancing itself on tree branches.
3. The pigeon has a broad tail, which helps it stop suddenly.
4. The duck and goose have small tails.

VII. Birds Can Be Helpful and Harmful

A. Most birds are quite helpful to man.
1. The crow, red-winged blackbird, bluebird, bluejay, quail, and pheasant eat grasshoppers.
2. The flicker eats ants, and the cuckoo eats caterpillars.
3. The sparrow, pheasant, and quail eat weed seed.
4. Some owls and hawks eat mice, moles, shrews, woodchucks, prairie dogs, and rabbits.
5. The buzzard and vulture are scavengers, eating dead animals.
6. The heron and crow eat dead fish.
7. The gull eats garbage that is thrown upon the water.
8. Game birds, such as the quail, pheasant, grouse, wild duck, wild goose, and wild turkey, are used for food.
9. Tame birds, such as the chicken, duck, goose, and turkey, are used for food.
10. The eggs of chickens and ducks are used for food.
11. The canary, parakeet, and parrot are kept as pets.

B. Some birds can be harmful to man.
1. Some birds, like the robin, bluebird, cedar waxwing, and wren, eat fruit and berries.
2. Some birds, like the crow, bluejay, and red-winged blackbird, eat grain.

3. Some hawks eat small insect-eating birds, young chickens, and young ducks.

VIII. The Conservation and Protection of Birds

A. Large numbers of song birds and game birds have been destroyed since the United States was established.

B. The destruction of nesting sites cannot be avoided when forests are cut, underbrush cleared, and fields burned.

C. However, much bird destruction is unnecessary and could be avoided.

1. The unnecessary drainage of marshes and the lowering of the water level in lakes and ponds take away the food supply and nesting sites of both water birds and wading birds.
2. In earlier times thousands of birds were killed for their feathers.
3. Vast numbers of birds are killed for fun or for food.

D. Both the states and the federal government have passed laws to help protect and conserve our birds.

1. Song birds cannot be killed at any time, nor can their eggs be collected.
2. Game birds can only be killed at certain times of the year.
3. However, birds, such as the starling, raven, crow, English sparrow, and certain harmful owls and hawks, can be killed at any time.
4. Feathers of wild birds cannot be brought into the United States except for educational purposes.
5. Agreements have been made between Canada, the United States, and Mexico to protect migrating birds.

E. The United States Department of the Interior controls the **Fish and Wildlife Bureau**, which has charge of conserving birds and animals, controls national wildlife reservations, and publishes educational bulletins about wildlife.

F. The **National Audubon Society**, together with its state and local chapters, publishes educational literature, pictures, slides, and films on birds and their habits, promotes laws to protect birds, and takes a yearly census of the bird population.

MAMMALS

I. Characteristics of Mammals

A. Mammals are members of the animal phylum called **Chordata.**

B. Together with fish, amphibians, reptiles, and birds, they make up a special group of animals called **vertebrates.**

C. As vertebrates, mammals have the following general characteristics.

1. They have backbones.
2. Their skeletons are inside their bodies.
3. They usually have two pairs of limbs, or appendages, attached to their bodies at the shoulder and hip.

D. Mammals also have their own special characteristics

E. All mammals have hair on their bodies, the hair growing from tiny pits in the skin.

1. Most mammals have much hair on their bodies.
2. The whale has almost no body hair, but it does have a few bristles.
3. Some mammals, like the mink, seal, beaver, and muskrat, grow thick coats of hair in the winter.

F. The hair of some mammals, like the weasel, arctic fox, and snowshoe rabbit, changes color in different seasons of the year.

1. In late spring, summer, and early fall their hair is brown.
2. In late fall they shed their brown hair

and grow white hair, which stays white all winter until the spring.

G. Some animals have hair that has been changed in form and structure.
   1. The porcupine's hair is in the form of quills.
   2. The armadillo's hair has been changed into horny plates that overlap and act like a coat of armor.
   3. The horns of the rhinocerous are made of masses of hair that have changed in form and structure.

H. Many mammals have fingernails and toenails growing from their skin.

I. All mammals have lungs for breathing.

J. All mammals are **warm-blooded,** which means that their body temperature is always the same, regardless of the temperature of the air or water around them.

K. All mammals have seven neck bones, but these bones are not the same size for all mammals.

L. Most mammals have two pairs of limbs.
   1. The whale and the manatee have lost their hind limbs, and their front limbs look like fins.
   2. The seal and the walrus have limbs in the form of flippers.
   3. The front limbs of the bat have very long finger bones with webbed skin between them, which the bat uses for flying.

M. Mammals have different numbers of toes on their legs, but there are rarely more than five toes on one leg.
   1. The horse walks and runs on one toe that has been changed into a hoof.
   2. The cow walks on a hoof that has been formed from two toes.
   3. Most of the smaller animals have separate toes, which help them walk and run.
   4. Some animals, like the lion and tiger, have powerful nails or claws on their toes, which are used for catching and ripping smaller animals.
   5. Animals, like the squirrel and raccoon, have claws that can bend, which are used for climbing trees.

N. The young of mammals are, with a very few exceptions, born alive.
   1. When mammals mate, the male deposits sperm inside the female, fertilizing the female's eggs.
   2. The female's eggs are very small and do not have enough yolk to feed the baby mammals while they are developing from the eggs.
   3. As a result, each egg becomes attached to the wall of an organ, called the **uterus,** in the female reproductive system.
   4. In the uterus the developing mammal receives food and oxygen from the mother's blood until it is born alive.
   5. It takes different periods of time for different mammals to develop from a fertilized egg into a baby mammal that is born alive.
   6. It takes about 21 days for a mouse, 30 days for a rabbit, 63 days for a cat or dog, 40 weeks for a human, 48 weeks for a horse, and 20 to 22 months for an elephant to be born after the female's egg has been fertilized.

O. All mammals care for their young after birth, and nurse them by giving them milk that comes from special glands, called **mammary glands.**

P. Mammals differ in size.
   1. Some mice and shrews are about 2 inches long and weigh less than 1 ounce.
   2. The largest mammal is the blue whale, which can be more than 100 feet long and weigh more than 150 tons.

Q. Mammals live in different places all over the world.
   1. Most mammals live on land.
   2. The whale and porpoise live in the ocean.
   3. The seal and walrus live in salt water and on land.
   4. The beaver, muskrat, and hippopotamus live in fresh water and on land.
   5. The mole and shrew live mostly underground.
   6. The monkey and tree squirrel live in trees.

7. The mountain sheep and mountain goat live on high mountains.
8. Bats live in caves.
9. The polar bear and reindeer live in very cold climates.
10. The lion and tiger live in very hot climates.
11. A large number of mammals live in the temperate climates.

R. Mammals eat plants and other animals.
1. Mammals, like the cow and the horse, that eat only plants are called **herbivorous** mammals.
2. Mammals, like the lion and the tiger, that eat only animals are called **carnivorous** mammals.
3. Mammals, like the bear and the raccoon, that eat both plants and animals are called **omnivorous** animals.

S. Some animals will move to different parts of the country, or **migrate**, at different seasons of the year.
1. Seals spend the winter in the Pacific Ocean between Alaska and California, and in the spring they travel to the Pribilof Islands, which are north of the Aleutian Islands, where the adult seals breed and new seals are born.
2. Elks live high in the mountains during the summer and lower down in the winter.

T. Some mammals, like the woodchuck and ground squirrel, are inactive, or **hibernate**, all winter.
1. During hibernation the animal's heartbeat slows down, the body temperature drops, breathing slows down to as little as once in 5 minutes, and the animal cannot be wakened.
2. Some mammals, like the bear, skunk, and raccoon, have a long winter sleep, where heartbeat and breathing slow down, and the mammal lives on stored food in its body.
3. This winter sleep is a little different from hibernation because mammals in winter sleep can wake up on mild days and then go back to sleep again, but animals in true hibernation cannot be wakened.

U. Mammals are classified into many smaller groups that have the same characteristics.

II. Egg-Laying Mammals

A. The Australian duck-billed platypus and the spiny anteater are mammals that lay eggs instead of giving birth to their young alive.

B. The duck-billed platypus has fur like a beaver, webbed feet like a muskrat, and a horny bill like a duck.
1. It lays two or three eggs, which look very much like reptile eggs.
2. When the eggs hatch, the young lap up a kind of milk given off by mammary glands on the mother's abdomen.

C. The spiny anteater is covered with long spines that look like porcupine quills.
1. It has a tubelike bill and a long tongue, which it uses to catch ants.
2. It lays two eggs, which it places in a special pouch on its lower side.

III. Pouched Mammals

A. This group includes such mammals as the kangaroo, opposum, the koala or "teddy bear," and the wallaby.

B. Their babies are helpless when they are born.

C. The newborn babies are immediately put into a special body pouch near the mother's mammary glands, which have nipples.

D. The babies feed on milk from the mammary glands until they are large and developed enough to leave the pouch.

E. Most pouched animals are found in Australia.

IV. Toothless Mammals

A. The sloth, armadillo, and great anteater are members of this group.

B. These animals are not completely toothless, but have no teeth at all in front.

C. The sloth is a bearlike animal that hangs upside down on trees and moves very slowly.
   1. It feeds chiefly on leaves.
   2. The hair of some kinds of sloths appears to be green because green algae grow in it.

D. The armadillo has a body that is covered with heavy, overlapping, bony scales.
   1. It feeds chiefly on insects.
   2. Its young are born either as identical twins or quadruplets.

V. Insect-Eating Mammals

A. This group includes the mole, the shrew, and the hedgehog.

B. The mole and the shrew eat large numbers of grubs and worms.

C. The mole has soft, fine fur, which is used in making coats and capes.
   1. It uses its sharp front legs to dig long burrows just underneath the surface of the ground, and lives underground.
   2. It has a long, sharp nose, which it uses for digging grubs and worms out of the soil.
   3. It has eyes that are blind.
   4. Moles are pests in lawns and golf courses.

D. The tiny shrew looks both like a mouse and a mole.
   1. It eats not only grubs and worms, but also mice and other shrews.

E. The hedgehog has long, quill-like hair, looks like a porcupine, and eats only insects.

VI. Flesh-Eating Mammals

A. All the members in this group have large, well-developed canine teeth, which are located near the corners of the mouth, and strong jaws for tearing flesh.

B. Their other teeth are pointed and help cut up the flesh.

C. Sea members of this group include the seal, walrus, and sea lion.

D. Land members of this group are divided into three subgroups, depending upon how they walk.
   1. One subgroup includes the bear and raccoon, which walk flat-footed on the soles of their feet.
   2. The second subgroup includes such mammals as the cat, dog, lion, tiger, wolf, and coyote, and these animals walk only on their toes.
   3. The third subgroup includes the skunk, weasel, mink, and otter, which walk partly on their toes and partly on the soles of their feet.

VII. Gnawing Mammals

A. This group includes such mammals as the rat, mouse, squirrel, chipmunk, prairie dog, woodchuck, rabbit, hare, muskrat, and beaver.

B. All but the rabbit and hare have two large, chisellike front, or incisor, teeth on each jaw.
   1. These teeth have very sharp edges, which stay sharp because the front edge is harder than the back edge so that the biting surface always wears out at an angle.
   2. The teeth themselves do not wear out because they keep growing all the time.
   3. The rabbit and hare have four of these teeth on each jaw.

C. They all have strong grinding teeth behind their sharp front teeth.

D. Most of the members of this group do a great deal of damage by eating grain and crops, and the rat spreads disease as well.

VIII. Hoofed Mammals

A. This group includes most of the tame animals that man uses for food, clothing, work, and transportation.

B. Biologists divide this group into two large subgroups: the odd-toed and the even-toed hoofed animals.

C. The odd-toed hoofed group includes such

animals as the horse and the rhinocerous.

D. The even-toed group is further divided into two smaller groups: the cud chewers and the noncud chewers.

E. The even-toed cud chewers include such animals as the cow, sheep, goat, camel, giraffe, and deer.
   1. They have four divisions to their stomach.
   2. They usually swallow large amounts of food quickly, and this food passes into the first stomach division, where it is stored for chewing.
   3. Later, the food is forced back into the mouth and chewed thoroughly as a cud.
   4. The cud then passes into the second stomach division, where it begins to be digested.

F. The even-toed noncud chewers include such animals as the pig and the hippopotamus.

G. Some hoofed mammals have horns.
   1. The cow, ox, and bison have hollow horns, which are never shed.
   2. The deer, elk, caribou, and moose have solid horns with many branches, and these horns are shed each year.

IX. Trunk-Nosed Mammals

A. The elephant is the only trunk-nosed animal alive today.

B. It is the largest land mammal, and can weigh as much as 7 tons.

C. Its trunk is really a stretched-out upper lip and nose.

X. Flying Mammals

A. Bats are mammals that fly.
   1. The toe bones of their front legs are very long and have skin stretched over and between them.
   2. The skin is also attached to the side of the body, the back legs, and the tail.
   3. This gives the bat a large wingspread.

B. Because the skin covers both the bat's front and back legs, the bat cannot walk very well.

C. The bat flies by night, and during the day it stays in caves, hanging upside down by the claws of its back legs.

D. Most bats eat insects, but the vampire bat in the American tropics drinks the blood of large animals.

E. Bats can fly in complete darkness without bumping into things.
   1. Bats can hear very well, and listen to the echoes of their own very high-pitched voices as the echoes bounce back from objects around them.
   2. This listening helps the bats determine where the objects are, and the bats fly around the objects rather than into them.

XI. Marine Mammals

A. The whale, dolphin, and porpoise are mammals that look like fish.

B. Although they have lungs and breathe air, they live all their lives in the ocean.

C. They use their tails for swimming and their finlike front limbs for balance.

D. They usually have one or two young, which are fed by their milk just like other mammals.

E. They eat fish and other sea animals.

XII. Flexible-Fingered Mammals

A. Members of this group include the lemur, monkey, gibbon, orangutan, chimpanzee, and gorilla.

B. Scientists also include man in this group but place him in a special family by himself.

C. Most mammals in this group have well-developed brains and a high intelligence.

D. They have fingers and toes that are very flexible, and can be used for grasping.

E. They all have nails on their fingers and toes, instead of claws.

F. The lemur and monkey live mostly in trees.

G. The higher apes are built very much like man.
  1. They have hairy bodies and no tails.
  2. Their front feet are used as grasping hands, and their back feet can be used both for grasping and walking.
  3. They can walk on two legs or move about on all four legs.

XIII. Mammals Can Be Helpful and Harmful

A. Some mammals are helpful to man, some are harmful, and others are neither helpful nor harmful.

B. Some mammals help man by eating pests.
  1. The fox eats field mice and rats.
  2. The mole and the shrew eat grubs and insects.
  3. The anteater and the bat eat insects.

C. Some mammals help by doing work for us.
  1. The horse and the ox are used for work in areas with temperate climates.
  2. The reindeer and sled dog work in cold areas, the camel in desert areas, and the elephant in tropical areas.

D. Some mammals supply us with food.
  1. We eat the food of such tame animals as the cow, sheep, goat, and pig.
  2. We also eat the meat of such wild animals as the deer, bear, and seal.
  3. We also get milk, cheese, butter, and lard from animals.

E. Some animals give us clothing.
  1. Mammals like the cow, horse, pig, and alligator give us leather.
  2. The sheep, camel, llama, alpaca, and vicuna give us wool.
  3. Mammals like the seal, beaver, muskrat, racoon, skunk, fox, chinchilla, and mink give us fur.
  4. Buttons and bone ornaments are made from the bones, hooves, and horns of such mammals as the cow, horse, and deer.

F. Mammals also supply us with tallow, lanolin, glue, and fertilizer.

G. Rats, mice, and guinea pigs are of great help in laboratories working on the causes and effects of diseases.

H. Some mammals are harmful to man.
  1. The gnawing mammals, like the prairie dog, woodchuck, rabbit, mouse, and rat, eat grain and crops.
  2. The rat and the mouse also eat or spoil our food, and spread disease.

XIV. The Conservation of Mammals

A. Many mammals have been killed without any thought being given to conserving them.
  1. Fur-bearing animals have been slaughtered in very great numbers.
  2. The bison of the Great Plains have almost been wiped out because of the demand for their fur and meat.
  3. In the West the elk, antelope, and mule deer have been killed in large numbers for their meat and horns.

B. Both the states and the federal government have passed laws to protect and conserve some of our wildlife.
  1. Some laws make it illegal to kill certain mammals at any time during the year.
  2. Other laws allow certain mammals to be killed only at special periods of time, and place a limit on the number of animals a person can kill during this period.

C. The federal government has established more than 400 game preserves for the protection of both mammals and birds.
  1. These preserves are the charge of the **Fish and Wildlife Bureau,** which is a wildlife conservation agency of the United States Department of the Interior.
  2. Many of these game preserves are in national parks and monuments, such as the Yellowstone National Park in the state of Wyoming.

D. Fur farms, where such mammals as the mink, muskrat, chinchilla, and silver fox are raised, help reduce the number of similar wild mammals from being killed.

LEARNING ACTIVITIES FOR "ANIMALS"

COMPOSITION AND CLASSIFICATION OF ANIMALS

1. *Examine animal cells* · Obtain a toothpick with a blunt end. Gently scrape the inside of your cheek a few times with the blunt end of the toothpick. Spread the accumulated material on a microscope slide. Add a drop of water, stain with a drop of tincture of iodine, and then cover the material with a cover glass. Examine the material carefully under the microscope until you find a clearly defined cell. Look for and identify the different parts of the cell. Compare this animal cell with a plant cell, such as an onion cell, prepared as described in Learning Activity 1 of "Plants Are Living Things," Chapter 13 (p. 466). Note both the similarities and differences between the plant and animal cells.

2. *Examine different cells and tissues* · Repeat Learning Activity 1 above, using some dried skin scraped from the palm of your hand. From the butcher obtain small amounts of fresh animal tissue, such as steak (muscle tissue), nerves, and bones, for study. Examine tiny slivers of these tissues under the microscope and note any differences in the cells. Because blood is also a tissue, examine a drop of blood under the microscope. Note that all the cells in a tissue are alike.

3. *Examine body organs* · Obtain such animal organs as a cow's or pig's heart, liver, stomach, lungs, kidney, and brains from the butcher. Examine their appearance and discuss the basic function of each organ. If actual organs are unavailable or inconvenient to obtain and handle, show pictures instead. Point out that each organ is made up of a group of tissues working together.

4. *System of animal classification* · Show how the cocker spaniel dog is classified, tracing the classification step by step from the phylum to the variety itself. Such a classification would appear as shown in Table 14–1.

TABLE 14–1. Classification of the Cocker Spaniel Dog

KINGDOM: Animal
  PHYLUM: Chordata (have a notochord)
    SUBPHYLUM: Vertebrata (have a backbone)
      CLASS: Mammalia (are mammals)
        ORDER: Carnivora (the flesh-eating mammals)
          FAMILY: Canidae (including the foxes and the wolves)
            GENUS: Canis (includes the wolf, coyote, and dog)
              SPECIES: familiaris (domestic dog)
                VARIETY: cocker spaniel

5. *The major animal phyla* · Visit a natural history museum and observe animals that belong to different phyla. If a field trip is not feasible, show pictures of representative animals from each phylum. Discuss some of the differentiating characteristics of the animals in each phylum, as seen in the museum or shown by the pictures.

6. *Compare vertebrates and invertebrates* · Obtain as many skeletons as possible of both vertebrates and invertebrates. If skeletons cannot be brought into the classroom, then visit a natural history museum or show suitable pictures. Compare the vertebrate and invertebrate skeletons. Point out the similarities in the vertebrate skeletons.

ANIMALS WITHOUT BACKBONES

1. *Collect one-celled animals* · There are several ways of collecting one-celled protozoans for classroom study. Very often protozoans can be found in the classroom aquarium. A second, almost infallible, source is the ponds and streams of parks and forests. To ensure ade-

quate collection, take two or three glass jars. Fill each jar half full of water from different parts of the edge of the pond or stream. If the pond water has green scum on it, put a mixture of water and scum into one of the jars. Also put some small water plants into each jar. Bring the jars back to the classroom and leave them uncovered in bright light, but not in direct sunlight.

Another way of collecting protozoans is by making a grass or hay infusion. Place a handful of dry grass, weeds, or hay in a large glass jar. Fill the jar with tap water that has been left standing for 2 or 3 days (to allow all the chlorine in the water to escape). Cover the jar and place it in a bright part of the room, but not in direct sunlight. Let the jar stand for 2 or 3 days, and then examine drops of the mixture under the microscope each day for the presence of protozoans. Usually the mixture will teem with different kinds of tiny animals by the end of the week.

The simplest way of transfering protozoans to a microscope slide is by using a medicine dropper. One drop on a slide is sufficient. Because protozoans cluster near the food they eat, try to include a little of the plant material in the drop.

The most common protozoan found in all of these sources is the paramecium. Representative samples of protozoans can be obtained from most scientific supply houses.

2. *Observe protozoans* · Examine drops of ameba, paramecium, and euglena cultures under the microscope. Be sure to cover each drop with a cover glass (Figure 14–1). These protozoans can usually be seen quite well under low power, but the high power may be quite helpful for observing fine details.

Have the children observe the form and parts of each protozoan. They can check their observations against pictures or drawings of the protozoan. Observe how each protozoan moves and obtains its food. Touch each gently with a pin and note its reaction to contact. Place a drop of culture first on a cooled slide and then on a heated slide and note the reaction to changes in temperature. Observe the reaction to strong light. Follow the movements of a large, well-formed protozoan. Perhaps you will be able to see how it reproduces by fission.

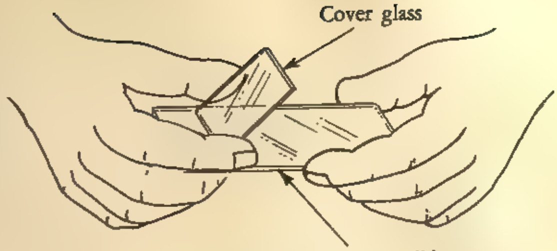


FIGURE 14–1.
COVERING A DROP OF CULTURE WITH A COVER GLASS.

3. *Disease-producing protozoans* · Have the children read about and give reports on such diseases as malaria, amebic dysentery, and African sleeping sickness.

4. *Examine a natural sponge* · Obtain a natural sponge. Have the children observe the many holes in the sponge. Let them feel the sponge, and then point out that this soft, flexible material is really the skeleton of the sponge. Have the children read about and report on how commercial sponges are collected and treated.

5. *Collect and observe hydras* · Hydras can be found attached to the submerged stems or the undersides of floating leaves of water plants in ponds. They are large enough to be seen with the naked eye. Tear off bits of plants to which the hydras are attached and place them in glass jars together with some of the pond water. In the classroom keep the jars in semidarkness and feed them a few tiny bits of lean meat once or twice a week.

Transfer one or two hydras to a saucer by using a medicine dropper with a wide tip. If necessary, break off part of the tip to make it wide enough to pick up the hydra without harming it. Place the tip of the medicine drop-

per directly over the hydra when sucking it up. After the hydra is in the saucer, add enough pond water to the saucer to keep the hydra covered.

Wait until the hydra has relaxed and stretched, and then examine it with a magnifying glass. Note the movement of the tentacles. Tap the saucer with your finger. The frightened hydra will contract to a tiny ball. The hydra will also contract if you touch it with a pin. Place one or two tiny bits of lean meat near the hydra and observe how the tentacles take the meat and bring it to the hydra's mouth. The tentacles will sting live tiny animals, such as water fleas or mosquito wigglers, that are placed near them. Look to see if any of the hydras are reproducing by forming buds. Cut a hydra into two or more pieces with a razor blade and place the pieces and pond water in a glass jar. In 2 or 3 weeks each piece will have become a new hydra. Finally, have one of the children turn a handspring to illustrate how the hydra moves. The child's hands will serve as tentacles.

6. *Observe jellyfish and sea anemones* · If you live near the ocean, look for small jellyfish and sea anemones in shallow water just off the coast. Place them in glass jars containing seawater, and observe their parts and behavior carefully.

7. *Examine coral* · If a sample of coral is available, have the children examine it and find where each coral animal lives. Note how the piece of coral is a solid mass of skeletons all joined together. Have the children read about and report how coral reefs are formed.

8. *Collect and examine planaria* · Planaria are often found in quiet ponds, either clinging to reeds or on the undersides of stones. You will have to look carefully because they are only ⅛ to ½ inch long and they blend so well with their surroundings that they are difficult to see. Suck up the planaria with a medicine dropper and keep them in jars filled with pond water. Bring back an extra supply of pond water. Planaria may also be obtained from scientific supply houses. Feed the planaria twice a week with a few tiny bits of lean beef or boiled egg yolk. It would be wise to change the water shortly after each feeding, using either the additional pond water you collected or tap water that has been allowed to stand for 2 or 3 days.

Observe the planaria with a magnifying glass or under the low power of a microscope. Note their spearlike heads and two dark "eyespots." See how planaria regenerate. Suck up three planaria with a medicine dropper and place them on a wet paper towel. By using a sharp razor blade, cut one planaria horizontally in half, the second planaria horizontally into thirds, and the third planaria vertically in half (Figure 14–2). After each planaria is cut, wash

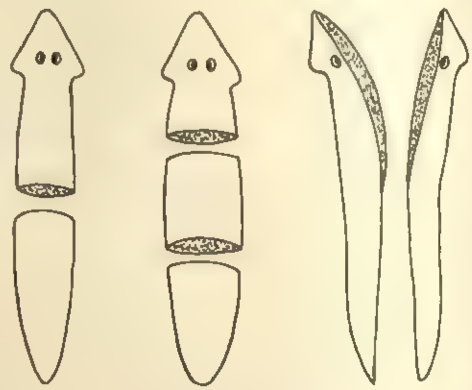


FIGURE 14–2.
WHEN PLANARIA ARE CUT INTO SEGMENTS, THEY REGENERATE.

the pieces in a saucer of pond water. Keep the saucers covered with glass squares to prevent evaporation. Feed and add water regularly. In about 2 weeks each piece will have become a new planaria.

9. *Parasitic flatworms and roundworms* · Have the children read about and report on the life history of such flatworms and roundworms as the tapeworm, fluke, ascaris, hookworm, and trichinella.

10. *Collect and observe earthworms* · The best place to find earthworms is in rich garden soil. Either dig them up or wait until after a heavy rain, when the worms come to the surface at night. Try to collect the large "night crawlers." Keep the worms in boxes containing equal parts of peat moss and rich garden soil. Cover the box with a damp piece of thick cloth towel. Keep the earth and towel damp, but not wet, at all times. About once a week feed the worms a quarter cup of oatmeal or bread that has been softened in water.

Place an earthworm on a damp paper towel and see how it crawls by lengthening and then contracting its body. Find the head of the earthworm by watching closely for the lip or pharynx that the worm pushes out as it moves along. Touch the head and note how the worm contracts the front part of its body; it may even crawl backward.

Pass your fingertips gently along the underside of the earthworm and feel the bristle feet or setae. Observe these feet through a magnifying glass. See what happens when you place the earthworm on a damp, smooth glass surface, where there is nothing for these bristle feet to grip.

Place an earthworm on a piece of damp paper towel and cover the earthworm with a saucer so the worm cannot escape. Keep the worm in a dark room for about an hour, and then shine a flashlight on the worm's head. Note how the worm quickly pulls its head away from the bright light.

11. *Examine a starfish* · If possible, obtain a preserved starfish. Feel the spines scattered all over the top part of its body. Look at the underside of the body and note the grooves that lead from each arm to the mouth in the center. Examine the tube feet with a magnifying glass. Have the children read about and report how the starfish opens up the shell of an oyster or clam.

12. *Examine a clam or oyster* · Obtain some clams or oysters from the fish store. Open the shellfish by inserting a knife on each side of the hinge and cutting the muscles that hold the shell together. Find the thin, fleshy mantle next to the surface of the shell. Look for the siphons and discuss their function. Find the muscular foot and note that it is attached to the body. Examine the shell and locate the mother-of-pearl layer. Show samples of materials that are either made of mother-of-pearl or else have mother-of-pearl in them.

13. *Collect and examine water snails* · Obtain some water snails from a pet shop or scientific supply house. Snails can be found among the water plants of a pond that has a muddy bottom. Place two or three snails in an aquarium or a large glass jar of tap water that has been allowed to stand for 2 or 3 days, making sure that there is a good supply of water plants in the container.

See how the snail uses its foot to move along the walls of the aquarium. Use a magnifying glass to watch the snail's rough "tongue" scrape the algae from the walls of the aquarium. Touch the snails and see how they withdraw into their shells and fall to the bottom of the aquarium. The snails may lay masses of transparent eggs on the walls of the aquarium. Examine these eggs periodically for 2 or 3 weeks and see them hatch.

14. *Collect and examine a land snail* · Land snails are often found early in the morning feeding on plants in the garden. They can be kept in an aquarium or in a large glass jar containing damp garden soil. If you use a glass jar, keep the mouth covered, either with a wire screen or with a screw top that has been perforated several times by a nail. Keep the snail well supplied with soft, green leaves or with lettuce.

Note how the snail's foot leaves a trail of slime, along which it travels. See how the snail quickly shreds the leaves and lettuce with its "tongue." Look for the eyes at the ends of the larger pair of feelers. Touch the feelers gently with a pencil and see how they retract. Touch the feelers more forcibly and make the snail withdraw into its shell.

15. *Observe squids and octopuses* • Have some children visit the natural history museum and observe specimens of squids and octopuses. Let them report on their observations and make a comparison of similarities and differences in form and structure. If possible, obtain and display pictures of these animals.

16. *Collect and observe crayfish* • The fresh-water crayfish and the ocean lobster are almost exactly alike, and either is highly suitable for the study of crustaceans. Crayfish are found in ponds and streams hiding under rocks and logs. They can be caught by tying one end of a string around a small piece of meat and dangling the meat near a rock at the bottom of the pond or stream. When the crayfish seizes the meat with its claws, pull up the string with a slow steady movement. If you are quick, you can also catch a crayfish by lifting up rocks and then grabbing it as it swims backward. Keep the crayfish you collect in large glass jars filled with pond water or tap water that has been allowed to stand for 2 or 3 days to allow any chlorine in the water to escape.

Observe the crayfish carefully. Note how the outside skeleton forms a hard, protective shield for the crayfish, especially over the head and chest area. Note the segments of the abdomen and the paddles of the tail. Count the number of jointed walking legs and examine the large pair of front claws. Feed the crayfish earthworms or small pieces of raw meat and see how the crayfish uses its claws and mouth parts. Locate the feelers and count how many there are. Observe the eyes and see how they move around on their stalks.

Put a crayfish on its back. Lift up the free, lower edge of the skeleton that covers the chest region and observe the gills. Find the mouth parts. Examine the swimmerets and see how the crayfish uses them. See how the crayfish uses its abdomen to swim backward quickly.

17. *Collect and observe water fleas (daphnia)* • Water fleas are tiny transparent crustaceans that can be found during the spring and summer in almost any quiet pool or stream. Because they eat algae, water fleas are easiest to find in ponds that are covered with green scum. A good way to catch them is to use a sieve or tea strainer that has been lined with cheesecloth. Use needle and thread to hold the cheesecloth against the sides of the sieve or strainer. Place the water fleas in glass jars containing pond water and a good supply of green algae, and keep the jars in sunlight. When you finish examining the water fleas, use them as food for fish, tadpoles, and hydra. They can also be placed in aquariums to remove excessive algae in the water.

Use a medicine dropper to suck up a water flea, and then place it on a microscope slide and examine it under the low power of a microscope. Because it is transparent, you will see not only the outer skeleton and the appendages, but also the inner organs. Notice the rapidly beating heart. Look for the intestine and trace it from the mouth to the anus.

18. *Collect insects* • To collect flying or jumping insects you will need a net, which you can either buy from a scientific supply house or make yourself. Untwist a wire coat hanger and shape the wire so that it forms a loop about 15 inches in diameter. Bend the ends of the wire so that they form two parallel straight pieces, and then cut off the ends to form a length of about 6 inches (see Figure 14–3). Obtain a broomstick and use a file to make parallel grooves 6 inches long on each side of one end of the broomstick. Put the ends of the wire into the grooves and wrap strong string tightly around the end of the broomstick until the wire is firmly attached to the stick. Make the net from cheesecloth or marquisette (the material used to make curtains). Make the net about 30 to 36 inches long and use strong thread to sew the net firmly to the wire loop.

To collect water insects, a net with a straight edge will help catch insects found on or below the surface of the water. To make a straight-edge net, follow the same instructions as described in the preceding paragraph, but shape the coat hanger wire into an equilateral tri-

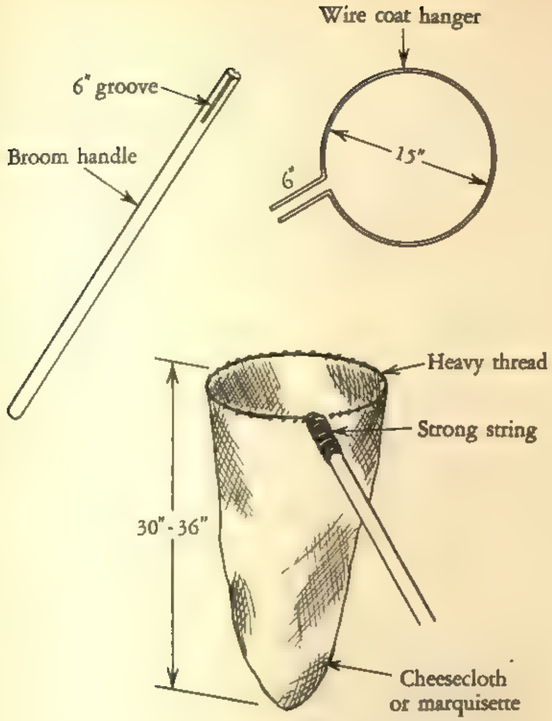


FIGURE 14–3.
A HOMEMADE NET FOR COLLECTING INSECTS.

angle instead of a circle. A kitchen strainer attached to a piece of wood or a broomstick is helpful in catching insects near the bottom of the pond or in dredging the bottom mud.

A variety of insects can be found feeding on or inside plants. Many of these, especially their larvae or caterpillars, can be picked by hand. Also, a large number of insects live in the ground, and are exposed when the soil is turned over with a shovel.

19. *Keep live insects* · Most land insects can be kept in wide-mouthed glass jars that have a few inches of soil on the bottom. Keep the soil moist, and feed the insects the kind of food they are accustomed to eat or were eating when you caught them. Always keep the mouth of the jar covered with cheesecloth or fine screen wire. Water insects should be kept either in balanced aquariums or in glass jars containing some of the water from which they were collected.

20. *Make an insect-killing bottle* · Place a large wad of absorbent cotton in the bottom of a wide-mouthed glass jar. Obtain carbon tetrachloride from a drugstore and pour it on the cotton until the cotton is saturated. Cover the cotton with a round piece of thick cardboard or blotting paper that has been perforated several times with a small nail (Figure 14–4). Keep the jar covered until you are ready to use it. When an insect is placed in the jar, the carbon tetrachloride fumes will kill it. For insects with delicate wings, like butterflies and moths, either put them into the killing bottle one at a time or else use separate jars. Keep hard-shelled insects, such as the beetle, in separate jars rather than together with the softer, more fragile insects. Add more carbon tetrachloride from time to time, as it evaporates from the cotton wad.

21. *Mount and display insects* · Insects should be mounted as quickly as possible. Otherwise they dry out and their bodies become brittle and break easily when handled.

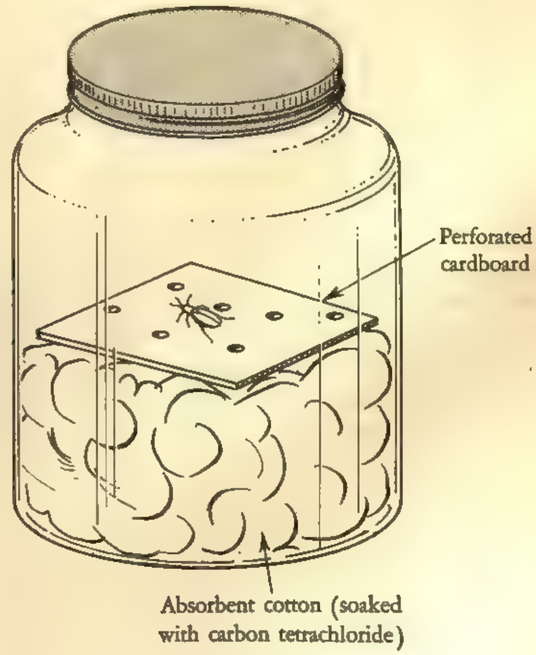


FIGURE 14–4.
AN INSECT-KILLING BOTTLE.

If the insects also become dry before they can be mounted, place them in a jar containing moist blotting paper, and keep the jar covered for 24 hours. In this way the insects will be softened enough so that they can be handled easily.

Insects such as flies, grasshoppers, and beetles can be mounted directly from the killing bottle. Use either common pins or regular mounting pins purchased from a scientific supply house. To mount an insect, insert just one pin through the chest or thorax a little to the right of the center line of the body (see Figure 14–5). Straighten the legs, antennae, and wings as they dry.

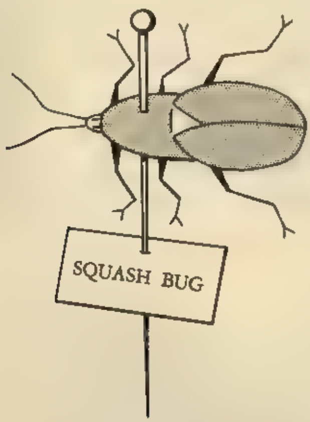


FIGURE 14–5.
A PROPERLY MOUNTED INSECT.

The large-winged insects, such as butterflies and moths, should be mounted on a spreading board. You can either purchase such a board from a scientific supply house or you can make one yourself. Obtain two pieces of wood, each about 8½ inches long and 2 inches wide. Cut out two pieces of corrugated cardboard, each about 12 inches long and 4 inches wide. Now glue the ends of the two pieces of cardboard to the two pieces of wood, as shown in Figure 14–6, so that there is a space of about ½ inch between the two pieces of cardboard. Place the body of the butterfly in the space and spread out the wings so that their colors and markings

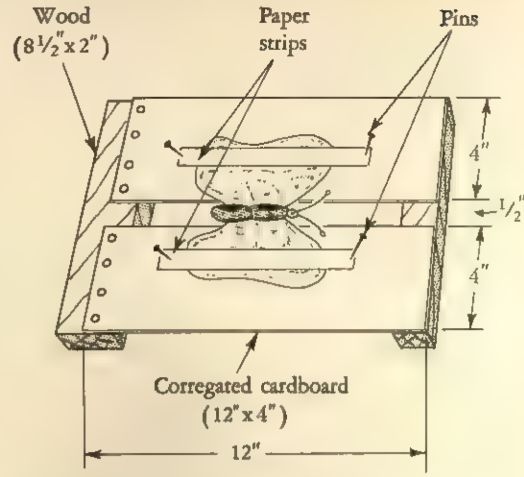


FIGURE 14–6.
A SPREADING BOARD FOR MOUNTING LARGE-WINGED INSECTS.

are shown to the best advantage. Hold the wings down with strips of paper and pins, making sure to push the pins into the corrugated cardboard and not into the wings. If necessary, hold the antennae down the same way. Keep the butterfly on the spreading board for a week before mounting.

Some insects will be too small to be pinned. For such insects make a small pennant from stiff paper or thin cardboard, glue the insect to the tip of the pennant, and then push the pin through the broad end of the pennant (Figure 14–7).

Make a mounting box by gluing corrugated cardboard to the bottom of a cigar box or wood box. A thin layer of felt or absorbent cotton on the bottom will produce a more attractive appearance. Arrange the insects on their pins so that when they are mounted in the box they will all be about the same distance from the bottom of the box. A small, neat label should be placed below the insect (as shown in Figure 14–5). The label should contain the insect's common name and scientific name, the place collected, the date, and your name. If this label is too bulky, you may want to write just a code number and have the explanatory chart beside the mounting box. When the pinned insects

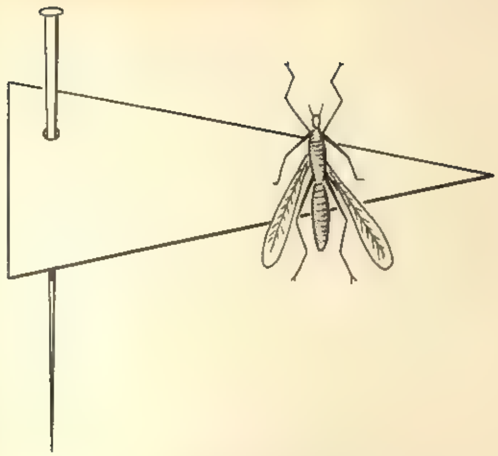


FIGURE 14–7.
MOUNTING A SMALL, DELICATE INSECT.

are in the desired position, push the pin firmly into the bottom of the box.

22. *Collect and examine grasshoppers* · Catch a live grasshopper and put it in a large glass jar together with some twigs, leaves, and blades of grass. Keep the jar covered with a lid that has several holes punched in it. Notice the division of the body into three regions. Locate and identify the parts attached to the head and the thorax. Point out the difference in size of the legs. Watch the grasshopper eat, and observe how it chews its food. Tap the side of the glass jar and note how the grasshopper jumps. See how the color of the grasshopper blends in with the color of the leaves and grass. When you hold the grasshopper between your finger and thumb, it will "spit molasses." This brown liquid is partially digested food from the grasshopper's crop.

Catch a live grasshopper and preserve it in a jar containing 70 percent alcohol. Examine the preserved grasshopper with a magnifying glass. Look at the eyes and the antennae. Find out how many mouth parts it has. Spread out and observe the outer and inner wings. Examine the sides of the abdomen and find the holes that are the openings of the grasshopper's breathing tubes.

Trace the life cycle of the grasshopper, using appropriate pictures or drawings. Note that the very young grasshopper has no wings, but develops them after it has molted a few times.

23. *Collect, examine, and compare butterflies and moths* · Collect a few specimens of butterflies and moths and examine them closely. Because many moths have colored wings, identify the moths and butterflies by comparing the size of their abdomens, the appearance of their antennae, and the position of their wings when at rest. Observe the bodies, legs, and wings of the moths and butterflies closely with a magnifying glass. Examine the scales of a butterfly's wing under the microscope and note the beautiful patterns and colors. Rub the scales off the wing with your fingers, and see how the wing begins to resemble that of a fly or bee. The vertical lines are the veins of the wing.

Place a toothpick or pin under the long, coiled, sucking tube of the butterfly or moth and gently pull the toothpick away from the insect's head, causing the tube to unroll. Point out that the butterfly and moth use this long tube to suck nectar from deep within the flower.

24. *Collect caterpillars, crysalids, and cocoons* · Collect caterpillars and place them in glass jars containing moist soil and some of the leaves upon which they were found. Each jar should also have a twig to support the crysalids or cocoons when they are formed. Cover the mouth of the jar with either fine screen wire or with the cover lid after it has been perforated several times with a small nail. Put only one caterpillar in a jar to determine whether the caterpillar is a butterfly or moth larva. Continue feeding the caterpillar until it passes into the pupa stage. If the caterpillar is a butterfly larva, it will form the hardened case called a crysalis. If the caterpillar is a moth, it will spin a cocoon.

Additional crysalids and cocoons may be collected in the garden and woods. You will have to look carefully because they often resemble dead leaves or twigs. Place each crysalid or

cocoon in a glass jar with a perforated cover or fine screen wire over the mouth. The jars should contain some moist soil and a twig for the adult moths or butterflies to stand on when they come out of their containers. Keep the jars in a warm place and examine the crysalids and cocoons regularly until the adult moths and butterflies emerge.

25. *Observe ants* · Look for ants in the school yard or at home. Examine them closely. Note the three parts of their bodies and their six legs, all connected to the chest or thorax. Look at the antennae, eyes, and jaws of an ant under a magnifying glass. Note how the ant is always cleaning its antennae. If one ant meets another, watch and see if they touch antennae.

Follow the ants to their nest. If the nest is under a rock, lift up the rock and examine the tiny larvae and pupae. Try to find the queen ant. Observe the behavior of the disturbed ant workers.

If you find ants climbing up plants or bushes, watch them. They may lead you to the tiny plant lice called *aphids*. If they do, use a magnifying glass to watch an ant stroke an aphid with its antennae.

26. *Make an ant nest* · Find an ant colony and dig up some of the ants, being sure to include the queen ant, which is larger than the other ants. If possible, collect some ant pupae, which are in large white cases. Place the ants in a large glass jar half filled with moist, sandy soil. Cover the mouth of the jar with a piece of fine mesh nylon stocking, and hold the nylon mesh firmly in place with rubber bands snapped around the neck of the jar. Place a cardboard carton over the jar and leave the jar in complete darkness for about a week.

The ants will build a new nest, and some of their tunnels may be made along the sides of the glass so that you can observe the ants' activities. Remove the carton for short periods of time and watch what the ants do in their nest. Feed the ants one or two drops of honey, some grains of sugar, a few bread crumbs, or some small dead insects. Remove any food the ants do not carry away after 20 minutes. Keep the soil moist, but not wet.

27. *Collect and examine insects of different orders* · Look for and collect insects that represent insect orders other than those already mentioned in the learning activities above. Representative insects that could be collected would be the dragonfly (for the dragonfly order), the water bug or bed bug (for the true bug order), the aphid or cicada (for the aphid order), the housefly, fruit fly, or mosquito (for the fly and mosquito order), and the ladybug, Japanese beetle, potato beetle, or boll weevil (for the beetle order).

Examine the different insects under a magnifying glass or the low power of a microscope. Describe and compare, wherever possible, their wings, antennae, mouth parts, and legs. Trace the kind of metamorphosis that each insect order undergoes. Discuss their food habits and decide whether they are helpful or harmful insects.

28. *The protective coloration of insects* · Have the children read about and report on protective coloration in insects. Try to collect pictures showing insects that look like their surroundings, insects that look like other more dangerous insects, and insects that look like the objects upon which they are resting.

29. *Helpful and harmful insects* · Make a list of helpful and harmful insects that can be found where you live. For the harmful insects, indicate whether they are harmful in the larval stage or in the adult stage. Have the children prepare a report about how the harmful insects can be controlled.

30. *Collect and examine spiders* · Collect some garden spiders, putting each in a separate, large glass jar. Put a few twigs or small branches in each jar for the spider to spin its web. Place a very small moist sponge in the jar because the spider needs water. Cover the mouth of the jar with a piece of fine mesh nylon stocking, and hold the nylon mesh firmly

in place with rubber bands snapped around the neck of the jar. Feed the spider live insects only, such as flies, moths, or other flying insects. Keep the sponge moist at all times.

Examine the spider carefully, using a magnifying glass whenever necessary, and compare the parts of a spider with those of an insect. Note the spider's two body parts: the combined head and chest (thorax) and the abdomen. Count the eight legs of the spider, and also the eight simple eyes. Note the large poison fangs at the spider's mouth.

If the spider spins a web, note what part of the body the silk thread comes from. Put a live insect in the jar and observe how the insect becomes trapped in the web. The spider will then wrap the body of the insect completely with its silk thread. Note that the spider will not eat the insect, but will suck out all the insect's body juices, leaving the dried skeleton behind.

ANIMALS WITH BACKBONES

1. *Set up a balanced classroom aquarium* · A rectangular tank that holds 6 gallons is an excellent size for elementary school classrooms. Clean the tank thoroughly with detergent and water, and rinse it several times. Obtain enough aquarium gravel from the pet shop to cover the bottom of the tank to a depth of 2 inches. Before adding the gravel to the tank, place the gravel in a large pan, tilt the pan to one side, and allow running water to flow in and overflow the pan. Continue running the water into the pan until the gravel is quite clean.

Place the gravel evenly in the tank, add one or two colored rocks, and put a few clam or oyster shells in the gravel. The shells will slowly dissolve in the water and provide the calcium that the growing snails will need for their shells.

Place a piece of paper over the gravel so that, when water is poured into the tank, the water will not become cloudy for a long time. Use either clear pond water or tap water that has been allowed to stand for 2 days so that the chlorine dissolved in it can escape. Pour water in the tank until it is about 1 inch from the top.

Place the tank in north or east light, but not in direct sunlight. From the pet shop obtain some rooted plants, such as sagittaria or vallisneria, and some floating plants, such as elodea or cabomba. Place the plants toward the back of the tank so you will have a clear view of the fish. The water plants will take in the carbon dioxide given off by the fish and give off oxygen that the fish will need. Do not put in too many plants because they will grow and spread. Remove any dead or broken leaves. Allow the aquarium to stand for about a week until the water is clear and the plants are growing.

Now you are ready to add the fish. Do not overcrowd the aquarium. One inch of fish to a gallon of water is recommended. The 6-gallon tank will then hold either six one-inch fish or three two-inch fish. Try to obtain small, active fish, such as guppies, rather than the sluggish goldfish.

Add about 6 to 12 snails, also obtained from the pet shop, and then place a glass cover over the tank. Do not overfeed the fish because the water will become foul and the fish may be killed. Fish will eat prepared fish food, bread crumbs, bits of egg yolk, and oatmeal. Occasionally, give them small amounts of chopped earthworms or meal worms.

2. *Observe fish* · Observe the fish in your aquarium. Note the shapes and comparative sizes of the head, trunk, and tail regions. Identify the fins, and see which fins are paired. Observe how the fish use their fins and tail. Watch the eyes and see if they move. Note how the fish take in water through their mouths, and then force the water out through their gill covers. See how easily the fish can rise or sink in the water without using their fins very much. This movement is made possible by the inflation or deflation of the air bladder inside the fish.

Remove a small fish from the aquarium and wrap up the fish in wet absorbent cotton, leaving only the tail exposed. Place the fish on a

flat, glass dish and observe the tail under the low power of the microscope. If the fish flaps its tail, place a microscope slide on the tail. You will see the arteries, veins, and capillaries. Note the blood corpuscles moving through the blood vessels, quickly through the arteries and slowly through the veins. In the small capillaries the corpuscles almost move in single file. Switch to the high power of the microscope and observe the corpuscles. Do not keep the fish out of water this way for more than 15 minutes.

Obtain a small dead fish from the fish market. Examine the gill covers, and then lift them up to see the gills and the slits through which the water passes. If possible, dissect the fish and examine all its internal organs. Remove some of the scales from the side of the fish and examine them under a magnifying glass or the low power of a microscope. Count the number of curved lines or rays on each scale. Each ray represents a year's growth so you will be able to tell the age of the fish.

3. *Make a terrarium* · Make a terrarium as described in Learning Activity 14 of "Plants Are Living Things," Chapter 13 (p. 467). The terrarium makes an excellent home for frogs, toads, salamanders, turtles, and lizards.

4. *Observe frogs and toads* · Frogs and toads live very well in a terrarium. Place a frog and a toad in separate cartons and watch them closely for a time. Compare their appearance, skin, and color. Touch their skin to see if it is wet or dry. Compare the way they hop. Count the number of toes on each foot and see if the frog and toad have the same amount of webbing between their toes. Bring your finger very near their eyes and see if they can wink. Locate their large ears, which correspond to a human's middle ear.

Place the frog and toad in separate, covered glass jars for a few minutes. Introduce some live house flies or fruit flies into each jar and see how the frog and toad use their tongues to catch and eat the flies. Note how the eyes move inward to help the frog and toad swallow their food. Frogs and toads eat living insects only, such as flies, grasshoppers, caterpillars, June bugs, roaches, and meal worms. They can also be trained to eat bits of lean beef and liver if the meat is dangled in front of them with a string.

Place a frog in a large aquarium containing no more than 5 or 6 inches of water. Watch how the frog swims. Note that when the frog is resting, it keeps its eyes and nostrils above the water. If you should hold the frog under water and gently rub its sides, it will usually croak. Replace the water in the aquarium with very cold water, and see how the frog becomes motionless, as if it is ready to go into hibernation.

5. *Raise tadpoles* · Frogs and toads lay their eggs in the spring. The eggs are found in shallow, quiet pond water, floating at or just beneath the surface near water plants. Frogs' eggs are found in clumps, whereas toads' eggs are found in strings. Both kinds of eggs are embedded in a jellylike material. Collect the eggs with a cup and pour them into a glass jar containing some of the pond water.

Place the eggs in an aquarium that has lots of water plants growing in it. If possible, add some of the green scum (algae) that is often found floating on top of ponds. Have the aquarium only partly full of water, and put a large rock in the aquarium that juts above the water. This rock will allow the tadpoles to leave the water and crawl around.

Watch the eggs each day with a magnifying glass. After a few days, tiny tadpoles will appear. Observe their growth and accompanying changes. Note that the toad's tadpole stage does not last as long as the frog's tadpole stage. Feed the tadpoles algae (green pond scum), small living insects, and dried fish food.

6. *Keep and observe salamanders* · The land salamanders can be kept very well in the woodland terrarium described in Learning Activity 3 above. Water salamanders can be kept in the balanced aquarium described in Learning Activity 1 above. They both can be fed earth-

worms, meal worms, ground lean beef, and liver cut into small pieces. It is better to feed the water salamander in a shallow pan of water outside the aquarium to avoid contamination of the water in the aquarium.

Observe the salamander closely. Although it may look like a reptile, it is really an amphibian and has all the characteristics of an amphibian. Touch the salamander's body gently with the palm of your hand and see how smooth and moist the skin is. Observe how small and weak the legs are. Count the number of toes on the front and hind legs, and see if the toes are webbed and have claws. Watch how the water salamander uses its tail for swimming. See how the salamander seizes and eats its food. Find out if the salamanders are attracted or repelled by strong light. Compare the salamander with other amphibians, such as the frog and toad, and note the similarities and differences. Contrast their living, feeding, and breeding habits as well.

7. *Keep and observe turtles* • The box turtle, which is mostly a land turtle, can be kept in the woodland terrarium described in Learning Activity 3 above. Water turtles can be kept in an aquarium tank that has about 3 inches of water, with a few flat stones jutting above the surface of the water. Feed the turtles earthworms, meal worms, tadpoles, snails, bits of raw hamburger, slices of apple and banana, berries, and small pieces of lettuce. Because water turtles eat only under water, be sure to throw the food directly into the water. Also, do not become alarmed if both water and land turtles refuse to eat for long periods of time and become sluggish. This inactivity is quite usual, so leave them alone.

Observe the turtle closely. Examine the top and bottom shells closely, and see how the shells form an excellent means of protecting the turtle from enemies and injury. Poke the turtle's head gently with a stick and watch the turtle pull its head, neck, legs, and tail inside its shell. Bring the stick near the turtle's eyes and see if they can blink. Observe how the turtle seizes and eats its food. Try to find out if the mouth contains any teeth. Also note how the flexible neck can turn in all directions. Examine the short legs and count the number of toes on the front and hind legs. See if the toes are webbed and have claws. Observe how the water turtle swims. Review the characteristics of a reptile and see if the turtle meets all these characteristics. Have the children find out how to distinguish between a turtle, tortoise, and terrapin. Compare the turtle with other reptiles, such as the lizard and snake, and note the similarities and differences. Contrast their living, feeding, and breeding habits as well.

8. *Keep and observe snakes* • Garter snakes are easily found, and are very safe to keep and observe. When lifting the snake, hold it just behind the head with one hand and support the rest of the body with the other hand. When first captured, the frightened garter snake may give off a bad-smelling liquid. This liquid is not harmful and washes off easily. Bring the snake back to the classroom in a cloth bag or a pillow case with the mouth of the bag or pillow case tied securely.

Keep the snake in a large aquarium tank covered by zinc mesh (hardware cloth), which can be obtained from the hardware store. Get enough zinc mesh so that you can bend the edges down snugly against the sides of the tank (Figure 14-8). Then place at least two heavy bricks cater-cornered on the top frame of the tank. The mesh and the bricks will ensure that the snake does not escape. Place some rocks, one or two forked branches, and a pan of water in the aquarium. Clean the cage once a week by flushing the cage well with water. Wash the snake with water at the same time. Feed the snake small living animals, such as frogs, mice, lizards, tadpoles, earthworms, and other large insects. Snakes are especially hungry after they shed their skins so have plenty of food on hand at that time.

Observe the snake closely. Note how it moves. Locate the eyes and see if they blink. See if you can find any ears. Watch how and for what reason the snake uses its forked tongue. Observe how the snake seizes and eats its food. See if the snake has all the general

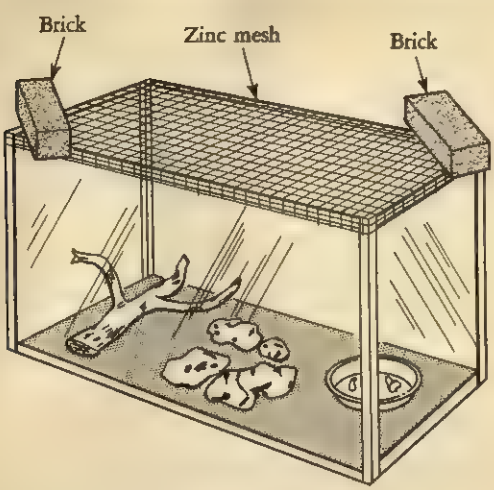


FIGURE 14-8.
PREPARING A CAGE FOR SNAKES.

characteristics of a reptile. Compare the snake with other reptiles, such as the lizard and turtle, and note the similarities and differences. Contrast their living, feeding, and breeding habits as well.

9. *Poisonous snakes* · Find out what kinds of poisonous snakes, if any, are found in your region. Obtain pictures of them and have the children learn to recognize them on sight. Learn where these snakes are most likely to be found and caution the children about these places. Find out what the proper first-aid treatment would be for bites from these snakes.

10. *Keep and observe lizards* · Collect skinks, swifts, geckos, or desert lizards, depending upon the part of the country in which you live. Also, chameleons can be purchased at the pet shop. Lizards can be kept in the woodland or desert terrarium described in Learning Activity 3 above. They can also be kept in an aquarium with a cover of hardware cloth (zinc mesh), recommended for keeping snakes in Learning Activity 8 above. Place some rocks, forked sticks, one or two potted plants, and a pan of water in the aquarium. Feed lizards all kinds of living insects, especially meal worms, ants, small grasshoppers, and flies.

Observe the lizard closely. Touch the skin and see if it is moist or dry. See how it uses its tail when it runs. Count the number of toes on each foot and see if they have claws. Observe how the lizard seizes and eats its food. Review the characteristics of a reptile and see if the lizard meets all these characteristics. Compare the lizard with other reptiles, such as the turtle and snake, and note the similarities and differences. Contrast their living, feeding, and breeding habits as well.

11. *Observe a baby alligator* · Children often receive stuffed baby alligators as souvenirs or gifts. If one is available, have it brought to school. Note that the alligator has all the general characteristics of a reptile, and point out the strong physical similarity between the alligator and the lizard. Have the children read about and report on the living, feeding, and breeding habits of the alligator.

12. *Observe birds* · Have the children bring in a parakeet, canary, or other pet bird for observation. Do not keep the bird in the classroom over the weekend in the winter if the room temperature will change during that time. Observe the bird closely. How many toes does it have, and how are they arranged? What kind of a beak does it have? For what uses are the legs, toes, and beak adapted? Does the bird walk or hop? Examine the bird's eyes and see if they can blink. Describe the color of the feathers on the head, back, breast, and tail. What kinds of sounds does the bird make? Observe how the bird eats, drinks, bathes, and dusts or oils itself.

Try to obtain a feather from a bird's wing or tail. Note how light and flexible, yet strong, the feather is. Examine the feather under a magnifying glass or the low power of a microscope. See how the barbs are held together by interlocking hooks.

Bring in some of the bones from a roasted chicken. Saw the leg and wing bones in half, and note that the bones are hollow, which makes them light. Have some children study and report on a bird skeleton from the natural history museum.

13. *Examine birds' nests* · Have the children bring in abandoned birds' nests. Let them consult reference books on birds, and try to find out what kind of bird built each nest. Pull the nest apart and sort out the materials. The children will learn not only the kinds but also the relative quantities of materials that were used to build the nest.

14. *Bird migration* · Have the children read about and report on the migration habits and destinations of birds. Find out which birds in your neighborhood do not migrate. Setting up a feeding station for birds would be very humane, especially when there is snow or ice on the ground. Have the children keep a record of the number of birds that visit the station.

15. *Adaptations and protective coloration of birds* · Post pictures or drawings of different kinds of birds' feet, beaks, wings, and tails. Include in each picture the names of the birds that have these kinds of body parts. Note how these parts are especially adapted for each bird's living and feeding habits. Look for pictures showing birds in their natural setting, which illustrate how the birds' coloring protects them by blending in with their surroundings.

16. *Keep and observe small mammals* · White mice, guinea pigs, and hamsters are excellent small mammals to keep and observe in the elementary classroom. Although different kinds of homemade animal cages can be built, it may be more expedient to purchase sturdy, well-built animal cages made of metal and of the proper size. The animals, together with suitable food and books on the care of these animals, can be obtained at a pet shop. There are also many reference books available on the care of pet mammals. When purchasing these animals, try to get young ones. They quickly become used to being around children and to being handled by them. Faithfully follow instructions for the care of these animals. Have the children note and compare the physical characteristics and the living and feeding habits of each animal.

17. *How animals care for their young* · Have the children read about and report on the different ways that animals feed, protect, and care for their young.

18. *Conservation of wildlife* · Have the children read about and report on the conservation of fish, birds, and animals. The children can obtain a copy of the game laws for their area or state and find out what kinds of animals are protected by law. They can also find out what laws have been passed by the government of the United States to protect wildlife. Show pictures or films on the establishment of fish hatcheries, bird refuges, and game preserves. You can write to the following organizations or agencies for literature on conservation: (1) The Conservation Foundation, 30 East Fortieth Street, New York 16, N.Y.; (2) your particular state conservation department, usually located in the state capital; (3) The National Audubon Society, 1130 Fifth Avenue, New York 28, N.Y.; (4) The National Wildlife Federation, 232 Carroll Street, N.W., Washington 12, D.C.; (5) United States Department of the Interior, Fish and Wildlife Service, Washington 25, D.C.

BIBLIOGRAPHY FOR "ANIMALS"

ABBOTT, ROBERT T. *Sea Shells of the World: A Guide to the Better-Known Species.* New York: Golden Press, 1962. 160 pp.

BALLARD, LOIS. *The True Book of Reptiles.* Chicago: Childrens, 1957. 47 pp.

BARKER, WILL. *Familiar Animals of America.* New York: Harper, 1956. 300 pp.

———. *Familiar Insects of America.* New York: Harper, 1960. 236 pp.

———. *Winter-Sleeping Wildlife.* New York: Harper, 1958. 135 pp.

BARR, DONALD. *The How and Why Wonder Book of Primitive Man.* New York: Grosset, 1961. 48 pp.

BARTLETT, RUTH. *Insect Engineers.* New York: Morrow, 1957. 128 pp.

BEVANS, MICHAEL H. *The Book of Sea Shells.* New York: Doubleday, 1961. 57 pp.

BLOUGH, GLENN O. *Animals Round the Year.* New York: Harper, 1958. 36 pp.

———. *Animals That Live Together.* New York: Harper, 1957. 36 pp.

———. *Animals and Their Young.* New York: Harper, 1958. 36 pp.

———. *An Aquarium.* New York: Harper, 1957. 36 pp.

———. *The Birds in the Big Woods.* New York: Harper, 1957. 36 pp.

———. *Discovering Dinosaurs.* New York: McGraw, 1960. 48 pp.

———. *The Insect Parade.* New York: Harper, 1957. 36 pp.

———. *The Pet Show.* New York: Harper, 1959. 36 pp.

———. *Useful Plants and Animals.* New York: Harper, 1959. 36 pp.

BROEKEL, RAY. *The True Book of Tropical Fishes.* Chicago: Childrens, 1956. 47 pp.

BROUILLETTE, JEANNE S. *Butterflies.* Chicago: Follett, 1962. 32 pp.

———. *Insects.* Chicago: Follett, 1963. 32 pp.

BUCHSBAUM, RALPH. *Animals Without Backbones.* Chicago: Univ. of Chicago Press, 1948. 405 pp.

BUCHSBAUM, RALPH, and LORUS J. MILNE. *The Lower Animals: Living Invertebrates of the World.* New York: Doubleday, 1960. 303 pp.

BURGER, CARL. *All About Fish.* New York: Random, 1960. 140 pp.

BURT, WILLIAM H., and RICHARD P. GROSSENHEIDER. *A Field Guide to the Mammals.* Boston: Houghton, 1956. 200 pp.

CARSON, RACHEL. *The Sea Around Us.* New York: Simon & Schuster, 1958. 165 pp.

CAVANNA, BETTY. *The First Book of Sea Shells.* New York: Watts, 1961. 39 pp.

CLARK, MARY LOU. *The True Book of Dinosaurs.* Chicago: Childrens, 1955. 47 pp.

COLBERT, EDWIN H. *Millions of Years Ago.* New York: Crowell, 1958. 153 pp.

COLLINS, HENRY HILL. *The Bird Watcher's Guide.* New York: Golden Press, 1961. 123 pp.

CRUIKSHANK, ALLAN, and HELEN CRUIKSHANK. *1001 Questions Answered About Birds.* New York: Dodd, 1958. 291 pp.

DARBY, GENE. *What Is a Frog?* Chicago: Benefic, 1957. 48 pp.

DARLING, LOIS, and LOUIS DARLING. *Sixty Million Years of Horses.* New York: Morrow, 1960. 64 pp.
———. *Turtles.* New York: Morrow, 1962. 64 pp.
DARLING, LOUIS. *Penguins.* New York: Morrow, 1956. 64 pp.
———. *Seals and Walruses.* New York: Morrow, 1955. 63 pp.
DILLON, WALLACE. *Salmon.* Chicago: Follett, 1962. 32 pp.
DUDLEY, RUTH. *Sea Shells.* New York: Crowell, 1953. 149 pp.
EARLE, OLIVE L. *Birds and Their Nests.* New York: Morrow, 1952. 64 pp.
———. *Paws, Hoofs, and Flippers.* New York: 1954. 192 pp.
ECKHOUDT, J. P. VANDEN. *A Butterfly Is Born.* New York: Sterling, 1960. 91 pp.
EPSTEIN, SAM, and BERYL EPSTEIN. *All About Prehistoric Cave Men.* New York: Random, 1959. 137 pp.
———. *Prehistoric Animals.* New York: Watts, 1956. 210 pp.
ERICKSON, PHOEBE. *The True Book of Animals of Small Ponds.* Chicago: Childrens, 1953. 47 pp.
FABRE, J. HENRI. *Insect Adventures.* New York: Dodd, 1958. 287 pp.
FENTON, CARROLL LANE. *Wild Folk at the Seashore.* New York: Day, 1959. 128 pp.
FENTON, CARROLL LANE, and EVELYN CARSWELL. *Wild Folk in the Desert.* New York: Day, 1958. 128 pp.
FENTON, CARROLL LANE, and MILDRED ADAMS FENTON. *The Fossil Book.* New York: Doubleday, 1958. 482 pp.
FENTON, CARROLL LANE, and DOROTHY CONSTANCE PALLAS. *Reptiles and Their World.* New York: Day, 1961. 126 pp.
FISHER, JAMES. *The Wonderful World of the Sea.* New York: Doubleday, 1957. 60 pp.
FRIEDMAN, ESTELLE. *Man in the Making.* New York: Putnam, 1960. 192 pp.
FRISKEY, MARGARET. *The True Book of Birds We Know.* Chicago: Childrens, 1954. 47 pp.
GAUL, ALBRO. *The Wonderful World of the Seashore.* New York: Appleton, 1955. 247 pp.
GOUDEY, ALICE. *Here Come the Bees.* New York: Scribner, 1960. 96 pp.
HARPSTER, HILDA T. *The Insect World.* New York: Viking, 1956. 211 pp.
HEGNER, ROBERT. *Parade of the Animal Kingdom.* New York: Macmillan, 1955. 675 pp.
HOGNER, DOROTHY CHILDS. *The Animal Book.* New York: Walck, 1958. 223 pp.
———. *Earthworms.* New York: Crowell, 1953. 51 pp.
———. *Frogs and Polliwogs.* New York: Crowell, 1956. 69 pp.
———. *Grasshoppers and Crickets.* New York: Crowell, 1960. 61 pp.
HOGNER, NILS. *Spiders.* New York: Crowell, 1955. 56 pp.
HOKE, JOHN. *The First Book of Snakes.* New York: Watts, 1956. 68 pp.
HOLSAERT, EUNICE. *Birds of the World.* New York: Simon & Schuster, 1958. 56 pp.
———. *A Book to Begin on Dinosaurs.* New York: Holt, Rinehart & Winston, 1959. Unpaged.

HUNTINGTON, HARRIET E. *Praying Mantis*. New York: Doubleday, 1957. 44 pp.

HUSSEY, LOIS J., and CATHERINE PESSINE. *Collecting Cocoons*. New York: Crowell, 1953. 73 pp.

HYDE, MARGARET O. *Animal Clocks and Compasses*. New York: McGraw, 1960. 157 pp.

HYLANDER, CLARENCE J. *Animals in Armor*. New York: Macmillan, 1954. 203 pp.

JOHN, BETTY. *Hummingbirds*. Chicago: Follett, 1962. 32 pp.

JOHNSON, GAYLORD. *The Story of Animals*. Irvington-on-Hudson, N.Y.: Harvey, 1958. 120 pp.

KIERAN, JOHN. *An Introduction to Birds*. New York: Doubleday, 1950. 77 pp.

KNOWLTON, WILLIAM. *Let's Explore Beneath the Sea*. New York: Knopf, 1957. 139 pp.

LAUBER, PATRICIA. *Penguins on Parade*. New York: Coward, 1958. 64 pp.

LAVINE, SIGMUND. *Strange Travelers*. Boston: Little, 1960. 150 pp.

———. *Wonders of the Hive*. New York: Dodd, 1958. 92 pp.

LEMMON, ROBERT S. *All About Moths and Butterflies*. New York: Random, 1956. 149 pp.

LEWELLEN, JOHN. *The True Book of Honeybees*. Chicago: Childrens, 1953. 47 pp.

Life, Editorial Staff, and LINCOLN BARNETT. *Prehistoric Animals*. New York: Simon & Schuster, 1958. 56 pp.

LOUVAIN, ROBERT, and the Staff of the Walt Disney Studio. *White Wilderness*. New York: Golden Press, 1958. 56 pp.

———. *Wildlife of the West*. New York: Golden Press, 1958. 56 pp.

LUBELL, WINIFRED, and CECIL LUBELL. *The Tall Grass Zoo*. Chicago: Rand McNally, 1960. Unpaged.

MARTIN, RICHARD A. *Butterflies and Moths*. New York: Simon & Schuster, 1958. 56 pp.

MASON, GEORGE F. *Animal Clothing*. New York: Morrow, 1955. 94 pp.

———. *Animal Habits*. New York: Morrow, 1959. 93 pp.

———. *Animal Homes*. New York: Morrow, 1947. 96 pp.

———. *Animal Sounds*. New York: Morrow, 1948. 96 pp.

———. *Animal Tails*. New York: Morrow, 1958. 95 pp.

———. *Animal Tools*. New York: Morrow, 1951. 94 pp.

———. *Animal Tracks*. New York: Morrow, 1943. 95 pp.

———. *Animal Weapons*. New York: Morrow, 1949. 94 pp.

McCLUNG, ROBERT M. *Bufo: The Story of a Toad*. New York: Morrow, 1954. 48 pp.

MEEKS, ESTHER K. *Snakes*. Chicago: Follett, 1962. 32 pp.

MORGAN, ALFRED. *An Aquarium Book for Boys and Girls*. New York: Scribner, 1953. 180 pp.

MURIE, OLAUS. *A Field Guide to Animal Tracks*. Boston: Houghton, 1954. 374 pp.

PARKER, BERTHA M. *Adaptation to Environment*. New York: Harper, 1956. 36 pp.

———. *Animals of the Seashore*. New York: Harper, 1958. 36 pp.

———. *Animal Travels.* New York: Harper, 1956. 36 pp.
———. *Animals We Know.* New York: Harper, 1957. 36 pp.
———. *Animals of Yesterday.* New York: Harper, 1958. 36 pp.
———. *Birds.* New York: Harper, 1958. 36 pp.
———. *Birds in Your Back Yard.* New York: Harper, 1959. 36 pp.
———. *Fishes.* New York: Harper, 1959. 36 pp.
———. *How Animals Get Food.* New York: Harper, 1959. 36 pp.
———. *Insects and Their Ways.* New York: Harper, 1958. 36 pp.
———. *Life Through the Ages.* New York: Harper, 1959. 36 pp.
———. *Living Things.* New York: Harper, 1958. 36 pp.
———. *Plant and Animal Partnerships.* New York: Harper, 1958. 36 pp.
———. *Reptiles.* New York: Harper, 1959. 36 pp.
———. *Saving Our Wildlife.* New York: Harper, 1957. 36 pp.
———. *Six-Legged Neighbors.* New York: Harper, 1958. 36 pp.
———. *Spiders.* New York: Harper, 1958. 36 pp.
———. *Toads and Frogs.* New York: Harper, 1957. 36 pp.
PARKER, BERTHA M., and RALPH BUCHSBAUM. *Balance in Nature.* New York: Harper, 1958. 36 pp.
PARKER, BERTHA M., and ALFRED E. EMERSON. *Insect Societies.* New York: Harper, 1955. 36 pp.
PARKER, BERTHA M., and ROBERT E. GREGG. *Insect Friends and Enemies.* New York: Harper, 1956. 36 pp.
PARKER, BERTHA M., and ILLA PODENDORF. *Animal World.* New York: Harper, 1958. 36 pp.
PARKER, BERTHA M., and WILLIAM S. WEICHERT. *Domesticated Animals.* New York: Harper, 1953. 36 pp.
PETERSEN, KAI. *Prehistoric Life on Earth.* New York: Dutton, 1961. 163 pp.
PETERSON, ROGER TORY. *A Field Guide to the Birds.* Boston: Houghton, 1947. 290 pp.
———. *A Field Guide to the Western Birds.* Boston: Houghton, 1941. 240 pp.
PHILLIPS, MARY GEISLER. *Dragonflies and Damselflies.* New York: Crowell, 1960. 95 pp.
———. *The Makers of Honey.* New York: Crowell, 1956. 164 pp.
PODENDORF, ILLA. *The True Book of Animal Homes.* Chicago: Childrens, 1960. 48 pp.
———. *The True Book of Animals of the Sea and Shore.* Chicago: Childrens, 1956. 47 pp.
———. *The True Book of Insects.* Chicago: 1954. 47 pp.
———. *The True Book of Pebbles and Shells.* Chicago: Childrens, 1954. 47 pp.
———. *The True Book of Spiders.* Chicago: Childrens, 1962. 47 pp.
POOLE, LYNN, and GRAY POOLE. *Weird and Wonderful Ants.* New York: Obolensky, 1961. 118 pp.
POPE, CLIFFORD H. *Reptiles Around the World.* New York: Knopf, 1957. 194 pp.
POSIN, DANIEL Q. *What Is a Dinosaur?* Chicago: Benefic, 1961. 48 pp.
REED, W. MAXWELL. *The Sea for Sam.* New York: Harcourt, 1960. 243 pp.
RIPPER, CHARLES L. *Hawks.* New York: Morrow, 1956. 64 pp.

ROGERS, JULIA ELLEN. *The Shell Book.* Newton Centre, Mass.: Branford, 1951. 503 pp.

ROOD, RONALD N. *The How and Why Wonder Book of Insects.* New York: Grosset, 1960. 48 pp.

RUSSELL, SOLVEIG PAULSON. *Saving Wildlife for Tomorrow.* Chicago: Melmont, 1960. 32 pp.

SCHEELE, WILLIAM E. *Prehistoric Man and the Primates.* Cleveland: World Pub., 1957. 121 pp.

SCHOENKNECHT, CHARLES A. *Ants.* Chicago: Follett, 1961. 32 pp.

———. *Frogs and Toads.* Chicago: Follett, 1961. 32 pp.

SCHULTZ, LEONARD P., and EDITH M. STERN. *The Ways of Fishes.* Princeton, N.J.: Van Nostrand, 1948. 264 pp.

SHUTTLESWORTH, DOROTHY. *The Age of Reptiles.* New York: Doubleday, 1958. 57 pp.

———. *The Story of Spiders.* New York: Doubleday, 1959. 56 pp.

STERLING, DOROTHY. *Insects and the Homes They Build.* New York: Doubleday, 1954. 125 pp.

STOUTENBERG, ADRIEN. *Wild Animals of the Far West.* Berkeley, Calif.: Parnassus, 1958. 150 pp.

SWAIN, SU ZAN N. *Insects in Their World.* New York: Doubleday, 1955. 53 pp.

SWINTON, WILLIAM ELGIN. *The Wonderful World of Prehistoric Animals.* New York: Doubleday, 1961. 88 pp.

TEALE, EDWIN WAY. *Grassroot Jungles: A Book of Insects.* New York: Dodd, 1950. 240 pp.

———. *The Junior Book of Insects* (rev. ed.). New York: Dutton, 1953. 249 pp.

TIBBETS, ALBERT B. *The First Book of Bees.* New York: Watts, 1952. 69 pp.

WASSON, ISABEL B. *Birds.* Chicago: Follett, 1963. 32 pp.

WEBB, ADDISON. *Birds in Their Homes.* New York: Doubleday, 1947. 66 pp.

WEIL, ANN. *Animal Families.* Chicago: Childrens, 1956. 31 pp.

WESCOTT, ALITA C., and CARLOTTA M. SCOTT. *What Is a Rodent?* Chicago: Benefic, 1962. 48 pp.

WILLIAMSON, MARGARET. *The First Book of Birds.* New York: Watts, 1951. 69 pp.

———. *The First Book of Bugs.* New York: Watts, 1949. 45 pp.

———. *The First Book of Mammals.* New York: Watts, 1957. 63 pp.

WOOD, DOROTHY. *Beavers.* Chicago: Follett, 1961. 32 pp.

ZIM, HERBERT S. *Alligators and Crocodiles.* New York: Morrow, 1952. 63 pp.

———. *Elephants.* New York: Morrow, 1946. Unpaged.

———. *Frogs and Toads.* New York: Morrow, 1950. Unpaged.

———. *The Great Whales.* New York: Morrow, 1951. Unpaged.

———. *Owls.* New York: Morrow, 1950. Unpaged.

———. *Snakes.* New York: Morrow, 1949. Unpaged.

ZIM, HERBERT S., and CLARENCE COTTAM. *Insects.* New York: Simon & Schuster, 1956. 160 pp.

ZIM, HERBERT S., and IRA N. GABRIELSON. *Birds.* New York: Simon & Schuster, 1956. 160 pp.

ZIM, HERBERT S., and DONALD F. HOFFMEISTER. *Mammals.* New York: Simon & Schuster, 1955. 160 pp.

ZIM, HERBERT S., and LESTER INGLE. *Seashores.* New York: Simon & Schuster, 1955. 160 pp.

ZIM, HERBERT S., and HURST H. SHOEMAKER. *Fishes.* New York: Simon & Schuster, 1956. 160 pp.

ZIM, HERBERT S., and HOBART M. SMITH. *Reptiles and Amphibians: A Guide to Familiar American Species.* New York: Simon & Schuster, 1956. 160 pp.

CHAPTER

15 The Human Body

THE MAKEUP OF THE HUMAN BODY

I. The Human Body Is Made of Cells

A. The human body is made up of millions of tiny cells.

B. These cells are not all alike.

1. Many cells have special work to do, and thus differ in size and shape, and they may even contain special materials.
2. This difference makes it possible for the cells to carry on their special kind of activity or work.
3. Examples of special kinds of cells include blood, skin, muscle, nerve, and bone cells.

C. A group of the same kind of cells that carry on the same activity or work is called **a tissue.**

D. There are five main kinds of tissue in the human body.

1. **Muscle tissue** includes all the muscles in the body.
2. **Nerve tissue** makes up the nerves and the brain.
3. **Skin tissue** includes the outer skin and the linings of such parts as the mouth, nose, throat, heart, stomach, liver, and intestines.
4. **Connective tissue** helps hold the body parts together and includes such materials as tendons, ligaments, cartilage, and bone.
5. **Blood,** even though it is a liquid, is also a tissue.

E. A group of different tissues, all working together, is called an **organ.**

1. An organ carries out a special activity or group of activities in the body.
2. Examples of organs include the heart, lungs, liver, stomach, eyes, ears, and brain.

F. A group of organs working together on a special body activity is called a **system.**

G. There are ten large systems in the human body.

1. The **skin system** covers the body, and includes the skin, hair, and nails.
2. The **skeletal system** supports the body, and includes the bones.
3. The **muscular system** makes it possible for the body and its parts to move.
4. The **digestive system** digests the food we eat, and includes such organs as the mouth, stomach, intestines, liver, and pancreas.
5. The **circulatory system,** or blood system, includes the heart, arteries, veins, and tiny blood vessels called the **capillaries.**
6. The **respiratory system,** or breathing system, includes such organs as the nose, windpipe, and lungs.
7. The **excretory system** gets rid of the waste products formed in the body, and

includes such organs as the kidneys and bladder.

8. The **nervous system** makes it possible for the body to respond to things around the body, and includes such organs as the nerves, brain, and spinal cord.
9. The **reproductive system** includes those organs that have to do with producing babies.
10. The **endocrine system,** or gland system, gives off special chemicals that control and regulate the action of the body.

II. The Regions of the Body

A. The human body is divided into three regions: the **head,** the **trunk,** and the limbs (arms and legs).
B. The trunk region is subdivided into two smaller regions: the **chest,** or **thorax,** and the **abdomen.**
C. There are three important cavities in the body.
   1. The **head,** or **cranial, cavity,** which contains the brain.
   2. The **chest,** or **thoracic, cavity,** which contains such organs as the heart, windpipe, and lungs.
   3. The **abdominal cavity,** which contains such organs as the stomach, intestines, liver, pancreas, kidneys, bladder, and reproductive organs.

THE SKIN

I. Parts of the Skin

A. The skin is a tissue, about ⅛ inch thick, that covers the body.
B. It has two layers: a thin outer layer, called the **epidermis,** and a thicker inner layer, called the **dermis.**
C. The outer layer (epidermis) is made up of many layers of cells.
   1. The outer cells are flat, scaly, and horny.
   2. These outer cells are dead and are constantly being rubbed off.
   3. As these dead cells are rubbed off, new living cells from the underneath layers push up and take their place.
   4. These new cells become flatter and harder as they come closer to the surface of the skin.
   5. If a spot on the skin, such as the side of the large toe, is rubbed very much, a large number of living cells may push up very quickly and form an extra thick layer of dead cells, called a **callus,** at that spot.
   6. The living cells of the epidermis have colored materials or pigments in them, which give the skin its characteristic color.
D. The thick inner layer (dermis) of the skin lies underneath the thin outer layer (epidermis).
   1. It is made up of tough connective tissue.
   2. In this connective tissue are blood vessels, nerves, oil glands, sweat glands, and cells that produce hair.
E. Beneath the dermis is a layer of fatty tissue that attaches the skin to the rest of the body.

II. Hair and Nails

A. Hair is a thread of horny material that is produced in the skin.
   1. This material is the same as the material found in the dead cells of the outer skin (epidermis).
   2. The hair is formed by cells located in the dermis, or inner layer, of the skin.
   3. The newly formed hair grows, passing up a tube through both the dermis and epidermis, and then moves out beyond the surface of the skin.

4. Although the root of the hair is alive, the rest of the hair is dead.
5. The hair grows until it reaches a certain length, and then falls out.
6. The length of a hair depends upon whether the hair is body, head, eyebrow, or eyelash hair.
7. When the hair falls out, a new one starts to grow in its place.
8. Oil glands in the skin produce an oil that flows into the tube where the hair is growing and helps keep the hair, as well as the surface of the skin, soft.
9. Inside the hair is a pigment that gives the hair its special color.
10. When persons become older, the hair pigment disappears and the hair becomes white.
11. Hair can be coarse, fine, straight, or curly.

B. Nails are also made of horny material that is produced in the skin.
1. This material is the same material found in the dead cells of the outer skin (epidermis).
2. The root of the nail is alive, but the rest of the nail is dead.
3. Fingernails grow about three times as fast as toenails.

III. Functions of the Skin

A. The skin has many important functions.

B. It acts as a protective covering to prevent harmful bacteria from entering the body.

C. It forms a waterproof covering, preventing water and other liquids from leaving the inner tissues.

D. It protects the inner parts of the body from such injuries as scratches, bruises, bumps, and cuts.
1. When the skin is injured, many of its cells are damaged or killed.
2. However, the skin is able to repair itself and form new skin.

E. The pigment in the skin helps protect the skin from the sun's rays.

F. The skin has very many nerve endings, which make the skin sensitive to touch, pressure, pain, heat, and cold.

G. The sweat glands in the skin help the body get rid of some of its waste materials.
1. Each sweat gland has a tiny tube leading from the surface of the skin to the lower part of the dermis, where the tube winds around and around to form a coil.
2. Tiny blood vessels surround the cells of the sweat glands.
3. The cells of the sweat glands take salt water, minerals, and other waste products from the blood, and the sweat then flows up the tube and out onto the skin, where the sweat evaporates.
4. There are more than a million sweat glands in the skin, spread out over the entire body, but they are more numerous in the palm of the hand, the sole of the foot, and under the armpit.

H. The sweat glands help control or regulate body temperature.
1. When it is warm outside, the sweat glands give off large amounts of sweat, which evaporates on the surface of the skin.
2. Water needs heat to evaporate, and takes this heat from the surface of the skin, thus cooling the body.
3. When it is cold outside, the sweat glands give off very little sweat, and only a small amount of evaporation and cooling of the body take place.

I. The blood vessels in the skin also help control or regulate body temperature.
1. When the body becomes warm, the blood vessels expand and allow more of this heated blood to flow into the skin.
2. The skin then becomes flushed with blood, making it possible for the heat to be conducted to the surface of the skin and then allowed to radiate off into the air.
3. When the body is cold, the blood vessels contract and prevent the heat of the body from escaping.

THE SKELETAL SYSTEM

I. The Structure of the Skeleton

A. There are more than 200 bones in the skeleton of the human body.

B. These bones are classified into four main groups: the **skull**, the **spinal column**, or backbone, the **ribs**, and the **limb** (arm and leg) bones.

C. In the skull there are the bones that form a case that surrounds the brain.

1. In children the joints between these bones are movable, allowing the bones to grow.
2. In adults the bones have grown together to form a solid case, and the joints cannot move.

D. The other important bones in the skull are the cheek, nose, and jaw bones.

E. The spinal column, or backbone, is made up of 33 blocklike bones, called **vertebrae**, one piled on top of the other.

1. These vertebrae make it possible for the head and trunk of the body to turn and bend in different directions.
2. They also form a strong support for the weight of the body and the head.
3. The spinal column also protects a large nerve called the **spinal cord**.

F. The skeleton has 12 pairs of ribs, forming a rib cage that protects the heart and lungs.

1. All 12 pairs are connected in back to the vertebrae of the spinal column.
2. The upper seven pairs of ribs are connected in front to the breastbone.

G. The arm is made up of a long bone that runs from the shoulder to the elbow, the two bones of the forearm, the wrist bones, the hand bones, and the finger bones.

H. Two pairs of bones join each arm at the shoulder.

1. The long, narrow collarbones connect the upper end of the breastbone with each shoulder.
2. The large, flat shoulder blades are at the back of each shoulder.

I. The leg is made up of a long bone that runs from the hip to the knee, a kneecap that protects the knee, the two bones that go from the knee to the ankle, the ankle bones, the foot bones, and the toe bones.

J. A number of hip bones together form the **pelvis**, and are connected to the vertebrae at the bottom of the spinal column.

1. The pelvis provides a firm support for the body.
2. It also allows the legs to move freely.

II. The Materials in the Skeleton

A. The skeleton is made of two kinds of material: **bone and cartilage.**

B. Both bone and cartilage are special kinds of connective tissue.

1. In bone a large amount of hard mineral matter, especially calcium phosphate, has been deposited between the cells, making the bone quite hard.
2. Cartilage has a soft and smooth material, which is tough and flexible, between its cells.

C. When a baby first begins to form inside its mother, its skeleton is mostly cartilage.

1. Soon after, the bone cells begin to replace the cartilage cells.
2. This change from cartilage to bone continues until the baby grows up and becomes an adult.

D. The adult skeleton still has some cartilage in it.

1. The ears and the end of the nose are made of cartilage.
2. There are discs of cartilage between the vertebrae of the spinal column.
3. The ends of the long bones are covered with cartilage.
4. The ribs are connected to the breastbone by strips of cartilage.

E. Many bones are hollow and have a soft tissue, called **marrow**, inside them.

F. There are two kinds of marrow: red and yellow marrow.

1. The red marrow is found in the ends of long bones, in the vertebrae, and in flat bones like the ribs, breastbone, and shoulder bone.
2. The yellow marrow is found in the center of the long bones.

III. The Skeletal Joints

A. The place where two bones meet is called a **joint.**

B. Some joints cannot move at all.

1. This lack of mobility occurs because the bones have grown together to form one solid mass.
2. Examples of immovable joints include the bones of the skull, breastbone, and hip bone.

C. Some joints, like the joint between the ribs and the backbone, are partially movable.

D. Some joints can move quite freely.

E. One type of movable joint is called the **hinge joint.**

1. A hinge joint works just like the hinge on a door and allows a bone to move back and forth easily.
2. The elbow and the knee are examples of hinge joints.

F. Another type of movable joint is called the **ball-and-socket joint.**

1. In this kind of joint the end of one bone forms a ball that fits into the hollow or socket of another bone.
2. A ball-and-socket joint makes it possible for a bone to move in many directions.
3. One example of this kind of joint is the shoulder joint, where the ball on the end of the upper arm bone fits into the socket of the shoulder bone.
4. Another example is the hip joint, where the ball on the end of the upper thigh bone fits into the socket of the hip bone.

G. The bones in both the hinge joints and the ball-and-socket joints are bound together by strong, tough bands of connective tissue, called **ligaments.**

IV. Functions of the Skeleton

A. The skeleton holds the body up and gives the body its shape.

B. It provides a place for the muscles to be attached, thus making it possible for the body to walk, breathe, and eat.

C. It protects delicate organs in the body.

1. The skull protects the brain.
2. The rib cage protects the heart and lungs.
3. The spinal column, or backbone, protects the large nerve that is called the spinal cord.

THE MUSCULAR SYSTEM

I. Kinds of Muscles

A. There are more than 400 different muscles in the human body.

B. The purpose of these muscles is to cause movement.

1. The muscles move and make other parts of the body move.
2. Every movement the body makes is done by muscles.

C. There are two kinds of muscles: **voluntary** and **involuntary** muscles.

D. Voluntary muscles are muscles we can control.

1. These muscles move whenever we want them to move.

2. The muscles that move the bones of the skeleton are voluntary muscles.
3. Some voluntary muscles, like the arm muscles, are connected to the bones by tough, white cords of connective tissue, called **tendons**, which do not stretch.
4. Some voluntary muscles are connected directly to the bones.
5. Some voluntary muscles, like the lip muscles, are connected to other muscles.
6. The cells of voluntary muscles are long and round, and are bound together by connective tissue into small bundles.
7. These voluntary muscle cells have cross-stripes, and the muscles are called **striated muscles**.

E. Involuntary muscles are muscles that we cannot control.
1. The action of these muscles is controlled by the nervous system.
2. These muscles produce all the movements needed to keep us alive.
3. They move food through the digestive system, blood through the body, and control breathing.
4. The cells of involuntary muscles are spindle-shaped and are found in layers in the walls of the digestive system, blood vessels, and other organs.
5. The cells do not have any cross-stripes, and the involuntary muscles are called **smooth muscles**.

F. The heart muscles are a special kind of muscle found nowhere else in the body.
1. The heart muscle is an involuntary muscle.
2. The muscles have cells that are not only cross-striped (striated), but branched as well.

G. Some muscles are both voluntary and involuntary.
1. They operate automatically without our control, but we can also control them.
2. The muscles that operate the eyelid and the diaphragm (for breathing) are both voluntary and involuntary.

II. How Muscles Work

A. Muscles work in only one way, by tightening or contracting.
1. When muscles contract, they become shorter and thicker, and in this way exert a pull.
2. Muscles can only exert a pull, never a push.

B. The voluntary skeletal muscles that move joints always work in pairs.
1. When one muscle works, the other muscle rests.
2. The muscle that bends the joint is called a **flexor**, and the muscle that straightens the joint is called an **extensor**.
3. The flexor **biceps** muscle on top of your upper arm makes the forearm move up, and the extensor **triceps** muscle underneath your upper arm makes the forearm move down again.
4. When the biceps contracts and works, the triceps rests and relaxes.

C. Voluntary muscles usually work singly, and either contract or rest.

FOOD

I. The Body Needs Food

A. The body needs food to live and grow.

B. In the foods we eat there are materials that give the body energy, materials that repair and build tissues, and materials that help regulate the activities of the body.

C. These necessary food materials can be divided into six main classes, **carbohydrates, fats, proteins, minerals, vitamins,** and **water.**

D. A person should eat different kinds of

foods to make sure that his body is getting all these necessary food materials.

II. Carbohydrates

A. Carbohydrates are used in the body to supply energy.

B. They are digested in the body to produce heat for warmth and energy for movement.

C. Carbohydrates include sugars and starches.

1. Honey, sugar, candy, ice cream, and pastry are foods that are rich in sugars.
2. Bread, potatoes, rice, cereals, spaghetti, and macaroni are rich in starches.

III. Fats

A. Fats are also used in the body to supply energy.

B. Fats produce twice as much energy as carbohydrates.

C. Butter, shortening, oils, salad dressing, bacon, and nuts are rich in fats.

D. When a person eats more carbohydrates than his body needs, the extra carbohydrates are changed into fat and stored in the body.

IV. Proteins

A. Proteins are very important food materials because they repair and build muscles and other tissues.

B. Proteins have nitrogen, which the body needs to repair and grow cells, tissues, and organs.

C. Children especially need proteins for growing.

D. Lean meat, fish, eggs, milk, cheese, whole wheat, beans, peas, and nuts are rich in proteins.

V. Minerals

A. The body needs small amounts of minerals for body growth, for the repair of body tissues, and for regulating some activities of the body.

B. Calcium and phosphorus are two important minerals the body needs.

1. Together with oxygen they make the hard material found in the bones and teeth.
2. Foods rich in calcium include milk, cheese, eggs, and leafy vegetables.
3. Foods rich in phosphorus include liver, nuts, peas, whole grain cereals, milk, cheese, eggs, and leafy vegetables.

C. Iron is an important mineral in the body.

1. Iron is present in the chemical that makes the blood red.
2. Foods rich in iron include liver, lean meats, eggs, green vegetables, and certain dried fruits such as prunes and raisins.

D. Iodine is important in regulating the activity of the body.

1. Iodine is present in a gland, called the **thyroid gland,** located in the neck.
2. This gland regulates the burning of the food in the body.
3. Iodine is found in seafood and in iodized salt.

E. Other important minerals include sodium, potassium, copper, and sulfur.

VI. Vitamins

A. Vitamins are chemical compounds found in foods.

1. They control or regulate certain activities in the body, and are important for body growth.
2. Although the body needs only very small amounts of these vitamins, without them the body develops certain diseases, called **deficiency diseases.**

B. When vitamins were first discovered, their chemical names were not known so they were first given letters of the alphabet as names instead.

C. **Vitamin A** keeps the lining of the nose, throat, and eyelids healthy.

1. A lack of vitamin A makes it difficult for persons to see clearly in dim light or at night.

2. A lack of vitamin A cuts down the body's resistance to colds and other infections.
3. A severe lack of vitamin A causes a serious eye disease that may result in blindness.
4. Vitamin A is found in the oils of fish livers and in milk, butter, eggs, tomatoes, and nearly all yellow and green vegetables.

D. **Vitamin B_1** (also called **thiamin**) helps control the digestion and use of carbohydrates in the body.
1. A mild lack of vitamin B_1 causes loss of appetite, poor digestion, headaches, tiredness, and irritability.
2. A severe lack of vitamin B_1 causes a serious nervous disease called **beriberi.**
3. Vitamin B_1 is found in whole grain foods and cereals, meat, milk, eggs, and green, leafy vegetables.

E. **Vitamin B_2** (also called **riboflavin**) is needed to help the cells in the body function properly, to keep the skin healthy, and to help control the digestion and use of carbohydrates in the body.
1. A lack of vitamin B_2 causes stunted growth, a disease of the mouth where the lips and tongue become cracked, and a scaly skin disease.
2. Vitamin B_2 is found in the same foods that have vitamin B_1.

F. **Vitamin P-P** (also called **niacin**) helps the digestive and nervous systems function properly, and is needed for the digestion and use of carbohydrates in the body.
1. A lack of vitamin P-P (niacin) causes a disease called **pellagra,** which produces skin rashes, a smooth tongue, digestive disturbances, mental disturbances, and paralysis.
2. Pellagra has been found in the South, where some farmers have been living mostly on molasses, corn, and salt or fat pork.
3. Vitamin P-P is found in lean meat, liver, milk, eggs, yeast, and green, leafy vegetables.

G. **Vitamin C** (also called **ascorbic acid**) regulates the use of calcium and phosphorus in the body and helps build and maintain healthy teeth and gums.
1. A mild lack of vitamin C produces sore gums, soft teeth, and weak blood vessels.
2. A severe lack of vitamin C causes a disease called **scurvy,** which produces bleeding gums, a swollen tongue, a tendency to bruise easily, bleeding around the bones, and sometimes teeth falling out.
3. Vitamin C is found in citrus fruits, tomatoes, green peppers, and green, leafy vegetables.

H. **Vitamin D** regulates the use of calcium and phosphorus in the body and helps build and maintain strong bones and teeth.
1. A lack of vitamin D produces soft bones and poor teeth.
2. Children who do not get enough vitamin D may develop a disease called **rickets,** where the bones grow out of shape and "bow legs" or "knock knees" are formed.
3. Vitamin D is found in fish liver oils, liver, eggs, and milk with vitamin D added to it.
4. The skin can make vitamin D when it is exposed to the ultraviolet rays of the sun.

I. **Vitamin K** (also called **menadione**) helps the blood clot.
1. It is used in blood injuries and in surgical operations to prevent loss of blood.
2. Vitamin K is found in tomatoes and green, leafy vegetables.

VII. WATER

A. Water is so important to the body that a person will die more quickly from lack of water than from lack of food.

B. All the cells in the body need water to function properly.

C. The body needs water to digest the food, absorb it, carry it to all parts of the body, and to get rid of the waste materials that are formed.

D. The body gets water in three ways.
1. Most of the foods have water in them.

2. Some water is formed when the food is burned in the body.
3. Water is taken into the body as drinking water or as milk and other liquids.

VIII. The Amount of Energy the Body Needs

A. The human body uses food to produce energy.

B. The amount of energy a person needs depends upon many things.

1. Larger persons need more energy than smaller persons.
2. Active persons need more energy than quiet persons.
3. Younger persons use more energy than older persons.
4. Males usually use up more energy than females.
5. Some persons have bodies that use up energy more quickly than the bodies of other persons.

C. The amount of energy a food will produce when it is digested in the body is measured in units called **Calories**.

1. Every bit of food that you eat will produce a certain number of Calories.
2. Some foods are richer in Calories than other foods.

D. If a person takes in more food Calories a day than his body can use, the extra food material is stored in the body as fat, and the person gains weight.

E. If a person takes in less food Calories a day than his body needs, the body now uses the stored fat, and the person loses weight.

IX. The Four Basic Food Groups

A. A balanced diet is a diet that gives the body all the food materials it needs in the right amounts.

1. About four sixths of the diet should be carbohydrates, one sixth fats, and one sixth proteins.
2. The diet should also contain the proper minerals and vitamins that the body needs.

B. Food experts have divided all the foods we need to keep healthy into four basic food groups.

C. If a person eats the proper amounts of food from each food group every day, he will have a balanced diet.

D. The four basic food groups are the milk group, the **meat group**, the **bread-cereal** group, and the **vegetable-fruit** group.

E. The milk group includes milk, butter, cheese, and ice cream.

1. A child should drink at least four glasses of milk a day.
2. A serving of butter, cheese, or ice cream can take the place of one of the glasses of milk.

F. The meat group includes meat, chicken, fish, eggs, beans, peas, and nuts.

1. A child should have at least two servings of meat, chicken, fish, or eggs a day.
2. Beans, peas, or nuts can be substituted occasionally.

G. The bread-cereal group includes whole-grain or enriched bread and cereals, spaghetti, and macaroni, and a child should have four or more servings from this group each day.

H. A child should have four or more servings from the vegetable-fruit group each day, with at least one serving of a citrus fruit and one serving of a dark green or deep yellow vegetable.

I. A balanced diet is helpful in many ways.

1. It helps a person grow normally.
2. It helps keep the body free of excessive and harmful fat.
3. It gives the body the energy it needs.

THE DIGESTIVE SYSTEM

I. Digestion

A. For food to be used by the body, it must enter the bloodstream, where it is carried to all the cells in the body.

B. The food we eat is too large and too complicated to be sent directly into the bloodstream for use by the cells.

C. Also, some of the foods we eat do not dissolve in water and could not enter the cells even if the food reached the cells.

D. Therefore, the foods have to be broken down, simplified, and changed into dissolved forms that the cells can use.

E. The changing of foods into a simpler, dissolved form that can enter and be used by the cells is called **digestion.**

F. Digestion is carried on by special organs that make up the digestive system in the body.

G. There are two parts to the digestive system: the **alimentary canal** and the **digestive glands.**

H. The alimentary canal is the food tube or passageway through which the food moves in the body.

1. It includes all the organs that act on the food and digest it.
2. The alimentary canal includes the **mouth, throat** or **pharynx, gullet** or **esophagus, stomach, small intestine, large intestine, rectum,** and **anus.**

I. The digestive glands include the **salivary glands, liver, pancreas,** the **gastric glands** of the stomach, and the **intestinal glands** of the small intestine.

1. These glands give off juices that enter the alimentary canal through small tubes, called **ducts.**
2. These juices contain powerful chemicals, called **enzymes,** that act on the foods and break them up into simpler, dissolved forms.
3. These simpler, dissolved forms can now be digested very easily.

II. Digestion in the Mouth

A. The purpose of the mouth is to prepare the food for digestion.

B. The teeth break up the food into smaller pieces.

C. There are different kinds of teeth in the mouth.

1. A child first gets a temporary set of 20 baby teeth, 10 on each jaw.
2. As the jaws grow larger, the child loses these baby teeth and grows a permanent set of 32 teeth, 16 on each jaw.
3. The four flat, sharp-edged front teeth on each jaw are called **incisors** and are used for biting and cutting.
4. The two long, pointed teeth, one on each side of the incisors, are called **canine** teeth and are used for tearing.
5. On each side of the canine teeth are two **premolars** and three **molars** (10 on each jaw), which have large surfaces and are used for grinding and chewing.

D. Most of the tooth is made of a hard, bone-like material, called **dentine.**

1. The part of the tooth above the gum is called the **crown,** and is covered with a very hard white material called **enamel.**
2. The root of the tooth fits into a socket in the jawbone.
3. The incisor and canine teeth usually have one root, and the premolar and molar teeth have two, three, or even four roots.
4. Blood vessels and nerves run up from the root into the hollow center of the tooth.

E. While the food is being chewed, it is mixed with a liquid called **saliva.**

1. The saliva comes from three pairs of **salivary glands,** located in the sides of the face and under the jaw.
2. The saliva moistens and softens the food, making it easy to swallow.
3. Saliva also contains an enzyme (chemical substance) that digests starch, chang-

ing it into sugars that can dissolve in water.

F. The tongue helps in chewing the food by keeping the food between the teeth, and helps in swallowing by pushing the food to the back of the mouth.

G. The food stays in the mouth for only a short time, is swallowed, and then moves by muscles down the throat and esophagus into the stomach.

III. Digestion in the Stomach

A. The stomach is a pear-shaped pouch located on the left side of the body under the lower ribs.

B. It is very elastic and can expand to hold large amounts of food.

C. The stomach's main function is to store the food and prepare it for digestion in the small intestine.

D. The food usually stays in the stomach for 2 to 3 hours.

E. The lining of the stomach has many glands, called **gastric glands.**

1. These glands give off a juice, called **gastric juice,** that flows through tiny tubes (ducts) into the stomach and mixes with the food.
2. The gastric juice contains an enzyme that breaks some proteins down into simpler materials.
3. The gastric juice also contains a strong acid, called **hydrochloric acid,** that dissolves minerals in the food and kills many bacteria that enter the stomach with the food.

F. The stomach has powerful muscles that keep contracting and relaxing, and this action churns the food back and forth.

G. This churning action breaks the food up into very small pieces and mixes these tiny pieces very thoroughly with the gastric juice.

H. The food then passes into the small intestine, a little at a time, through a valve at the intestinal end, which opens and closes regularly.

IV. Digestion in the Small Intestine

A. The small intestine is the main organ for digesting food in the body.

B. It is about 23 feet long and 1 inch thick.

1. Because it is so long, it coils back and forth many times inside the body.
2. The food stays in the small intestine much longer than in the stomach.

C. While the food is in the small intestine, the juices from three digestive glands pour into the small intestine: **intestinal juice, pancreatic juice,** and **bile.**

D. The intestinal juice is produced by glands in the lining of the small intestine.

E. The pancreatic juice is produced by the pancreas, which is a long gland that lies just behind the stomach, and the juice flows through a duct (tube) into the upper end of the small intestine.

F. The bile is a brownish-green liquid that is produced in the liver, which is a very large gland located in the upper right-hand part of the abdomen.

1. The bile flows into a sac, called the **gall bladder,** where it is stored until needed.
2. When food leaves the stomach and enters the small intestine, the bile flows into the bile duct, which joins with the pancreatic duct just as they both reach the small intestine.
3. Both the bile and the pancreatic juice enter the small intestine at the same time.

G. An enzyme in the bile breaks the fat up into simpler materials and at the same time the bile separates the fat into tiny droplets, which can be more easily attacked by enzymes from the pancreatic juice.

H. Both the pancreatic and intestinal juices have many enzymes that all together digest the carbohydrates, fats, and proteins, changing them into simple dissolved forms that can be used by the cells in the body.

I. After the food has been digested in the small intestine, it is then taken in or ab-

sorbed through the walls of the small intestine into the bloodstream.

1. The inside of the small intestine has many ridges and fingerlike projections or bulges, called villi, which absorb the simple dissolved forms of digested food.
2. The ridges and villi contain blood vessels that take in the food, and the bloodstream carries the food away to cells in all parts of the body.
3. Each cell takes the kind of food it needs and changes the food into living protoplasm.

V. The Function of the Large Intestine

A. The large intestine is about 5 feet long and 2 inches thick, and starts just below the small intestine.

B. Food that cannot be digested or used by the body passes from the small intestine into the large intestine as waste materials.

C. The waste materials also contain large amounts of bacteria that normally live in the small intestine.

D. The waste materials are quite watery at first.

1. They pass through the large intestine very slowly while the water is absorbed back into the bloodstream.
2. This removal of the water gives the waste material a more solid form, which is called feces.

E. The feces passes into the lower part of the large intestine, called the rectum, and then out through an opening, called the anus.

THE CIRCULATORY SYSTEM

I. The Function of the Circulatory System

A. The circulatory system is made up of the heart, blood, and blood vessels.

B. The heart pumps the blood, which moves through blood vessels, to every part of the body and back again in about 30 seconds.

C. The circulatory system has three main functions.

1. It carries digested food to the cells in the body.
2. It brings oxygen to the cells for burning the food and producing heat and energy.
3. It takes away the waste materials produced by the cells and carries these materials to organs that remove them from the body.

II. The Blood

A. Blood is a liquid tissue.

B. There are about 6 quarts of blood in the human body.

C. The liquid part of blood is called plasma.

1. The plasma is mostly water.
2. It has salts such as table salt (sodium chloride) and calcium salts dissolved in it.
3. It contains a special protein, called fibrinogen, which helps the blood clot.
4. It contains special materials, called antibodies, which fight disease.
5. It contains special materials, called hormones, which are given off by ductless (tubeless) glands in the body, and which help control the activities of the body.
6. The plasma also brings food particles to the cells and carries away waste materials.

D. There are three kinds of solid materials in blood: red cells, white cells, and platelets.

E. The red cells are the most numerous cells in the body.

1. They are more commonly called red corpuscles.

2. They look like very small discs that have had both sides pushed in.
3. They contain an iron compound, called **hemoglobin**, which gives them their red color.
4. Red cells pick up oxygen from the lungs and carry it to the cells in the body.
5. The cells use the oxygen to burn food, and carbon dioxide is produced as a waste material.
6. The red cells pick up the carbon dioxide and carry it to the lungs, where the carbon dioxide is given off.

F. The white cells are larger than the red cells, but they are less numerous: there is about one white cell to every 600 red cells.
1. White cells are more commonly called **white corpuscles.**
2. They are clear, colorless, and have no special shape.
3. They can leave the walls of the blood vessels and move around among the cells in the body.
4. Their purpose is to destroy bacteria and other disease germs.

G. The platelets are much smaller than the red blood cells.
1. They are irregularly shaped and colorless.
2. They help blood clot when the body is injured and bleeds.
3. Clotting helps prevent the body from losing too much blood and thus bleeding to death.
4. When a blood vessel is broken and begins to bleed, the platelets stick to the edges of the wound and begin to dissolve.
5. The platelets give off a chemical that unites with the calcium salts and fibrinogen in the plasma to form threadlike fibers.
6. The fibers form a net that slows the flow of blood, traps the corpuscles, and forms a clot that prevents the blood from escaping.

H. The normal temperature of an adult's blood is about 98.6 degrees Fahrenheit.
1. Some persons have a temperature a little above or below this average.
2. When a person is ill, the body temperature becomes higher than 98.6 degrees.

I. Harmful bacteria, disease germs, and worn-out blood cells in the blood are filtered and removed by the liver and the spleen.
1. The liver is quite large, and is located in the upper right-hand part of the abdomen.
2. The spleen is much smaller, and is located in the upper left-hand part of the abdomen in back of the stomach.
3. The spleen also stores blood and a reserve of red blood cells.

III. The Blood Vessels

A. The blood moves around the body in closed tubes called **blood vessels.**

B. There are three kinds of blood vessels in the body: **arteries, veins,** and **capillaries.**

C. Arteries are blood vessels that carry blood away from the heart.
1. A large artery leaves the heart and keeps branching into smaller and smaller arteries.
2. The smallest branches lead to every part of the body.

D. Veins are blood vessels that carry blood back to the heart.
1. There are tiny veins in every part of the body.
2. These tiny veins keep coming together to form larger and larger veins until a large vein that enters the heart is formed.

E. Veins are wider than arteries, and their walls are thinner and less elastic so that the flow of blood in the veins is slower than the flow in the arteries.

F. Capillaries are very tiny blood vessels between the smallest arteries and the smallest veins.
1. Some capillaries are so small that the blood cells must go through them in single file.
2. The blood from the smallest arteries flows into the capillaries, travels through

the capillaries, and then flows into the smallest veins.

3. All the cells in the body are next to some capillary.

G. The capillaries are the blood vessels that actually supply the cells of the body with the materials they need.

1. The walls of the capillaries are so thin that molecules of materials in the blood can pass into the cells, and molecules of materials in the cells can pass into the blood.
2. The blood gives the cells food, oxygen, and minerals, whereas the cell gives the blood carbon dioxide and other waste materials.

IV. The Heart

A. The heart is a strong muscle shaped like a pear and about as big as a fist.

B. It slants downward and is located to the left of the middle of the chest.

C. It acts as a pump by contracting and relaxing.

1. Whenever it contracts, blood is pumped out of it into the arteries.
2. Whenever it relaxes, blood flows into it from the veins.

D. The heart has two sides: a right side and a left side.

1. The two sides are completely separated by a wall called the septum.
2. Each side pumps blood separately from the other.
3. The blood in the two sides does not mix while it is in the heart.

E. The heart is also divided into four chambers or compartments.

1. The top two chambers are called **auricles.**
2. The bottom two chambers are called **ventricles.**
3. Thus we have a right auricle and a left auricle at the top, separated from each other by the septum, and a right ventricle and a left ventricle at the bottom, also separated by the septum.
4. The auricles receive blood from the veins in the body and pump it down into the ventricles.
5. The ventricles pump the blood into the arteries in the body.
6. Both auricles contract or pump at the same time, and both ventricles contract or pump at the same time.

F. The heart has valves that prevent the blood from flowing back into the auricles when the ventricles are contracting.

1. There is a flap of connective tissue between the opening of the right auricle and right ventricle, and also between the opening of the left auricle and left ventricle.
2. These flaps act like valves because they can only move one way.
3. When an auricle contracts, the flap is pushed aside, allowing the blood to move down into the ventricle.
4. But, when a ventricle contracts, the flap is pushed upward and closes the opening so that the blood cannot flow up into the auricle.

G. The large arteries also have valves, which are located just where the arteries leave the heart.

1. These valves are made of tissue, and are pushed aside when the blood leaves the heart and goes through the arteries.
2. When the blood tries to flow back into the heart, it pushes the valve shut, and this action stops the blood from flowing back.

H. Veins also have valves located all through the body, which prevent the blood from flowing back, and in this way force the blood to move toward the heart.

I. The sound of the heart beating is made by the closing of the valves between the auricles and ventricles of the heart and by the closing of the valves in the large arteries near the heart.

J. The contracting of the heart also makes the tip of the heart move back and forth so that you can feel the tip beating.

K. A **pulse** is the beat that can be felt in the

arteries every time the heart contracts, or beats.

1. The surge of blood through the arteries makes the artery walls expand and also produce a beat.
2. This pulse can be felt by placing the finger over an artery in the wrist or neck.
3. By counting the number of pulse beats in a minute, we can find out how fast the heart is beating, or contracting.

V. The Circulation of the Blood

A. There are really two large circulatory systems in the body.
  1. In one system the blood goes to the lungs and returns.
  2. In the other system the blood flows through the body and returns.

B. In the system that sends blood to the lungs, blood coming from all over the body enters the right auricle of the heart.
  1. The right auricle pumps the blood down to the right ventricle.
  2. The right ventricle then pumps the blood to the lungs.
  3. In this system the blood contains carbon dioxide, and, when the blood is sent to the lungs, it gives up the carbon dioxide and picks up oxygen.

C. In the system that sends blood to the body, blood coming from the lungs enters the left auricle of the heart.
  1. The left auricle pumps the blood down to the left ventricle.
  2. The left ventricle then pumps the blood to the parts of the body.
  3. In this system the blood brings fresh oxygen to the cells in the body, gives up the oxygen to the cells, and at the same time picks up carbon dioxide, which it brings back to the heart.

D. Each ventricle has only one artery leading from it.
  1. The artery leading to the lungs branches at about 1 inch above the heart, each branch going to one of the lungs.
  2. The other large artery passes down through the body and then branches at the legs, each branch going to one of the legs.

E. More than one vein comes back to the auricles.
  1. Four veins bring blood back from the lungs to the left auricle.
  2. Two veins bring blood back from the body, one vein coming from the head and arms, and the other vein coming from the lower part of the body.

F. In each system the large arteries keep branching again and again into smaller arteries and finally lead into capillaries; then the capillaries lead into small veins that keep coming together again and again to form the large veins.

VI. Lymph

A. As the blood flows through the capillaries, some of the plasma passes through the thin capillary walls and fills the spaces between the cells of the body.
  1. This liquid is called lymph.
  2. Lymph is the clear liquid that fills blisters and appears when the skin is scraped and bruised.

B. The lymph contains digested food, water, salts, and other materials.

C. The lymph bathes the cells and gives them food, and the cells give the lymph the waste products that have been formed in the cells.

D. The lymph returns to the bloodstream through special lymph vessels.
  1. The lymph collects in tiny tubes that join again and again to form larger tubes.
  2. These lymph vessels have valves, just as veins do.
  3. Exercise moves the lymph through the lymph vessels.
  4. The lymph finally collects in two large vessels that open into two large veins just above the heart.

E. Occasionally, the lymph vessels enlarge to form swellings called **lymph nodes.**

1. In the lymph nodes the lymph tubes break up into many smaller tubes again.
2. The nodes contain large numbers of special white blood cells that kill bacteria and other disease germs that may have entered the lymph from the cells in the body.
3. The function of the lymph nodes, then, is to filter and purify the lymph before it returns to the blood.
4. There are many lymph nodes concentrated in the neck, armpit, and groin.
5. These lymph nodes may swell and become painful when there is an infection in the part of the body where the nodes are located.

THE RESPIRATORY SYSTEM

I. Parts of the Respiratory System

A. The action in the cells that produces energy is called respiration.

B. In respiration the cells of the body take in oxygen, use the oxygen to burn the digested food and produce heat and energy, and then give off carbon dioxide.

C. The function of the respiratory system is to bring oxygen into the body and to get rid of carbon dioxide.

D. The parts of the respiratory system include the **nose** and **nasal passages**, the **throat** or **pharynx**, the **windpipe** or **trachea**, the **voice box** or **larynx**, the **bronchi**, the **bronchial tubes**, and the **lungs**.

E. Air enters the nose through two **nostrils**, which are separated by a wall called the **septum**.

F. The air then passes through the nasal passages, which are spaces that lie above the mouth.
1. In the nostrils and the front part of the nasal passages are hairs that trap dust and germs.
2. In the rear part of the nasal passages are hairlike materials, called **cilia**, which are always moving.
3. The cilia trap dust and other materials, and carry them toward the mouth, where they are either swallowed or coughed up.
4. The nasal passages have a soft lining, which gives off a liquid that is called **mucus**.
5. The mucus also helps trap dust and germs.
6. As the air passes through the nasal passages, it becomes warm and moist.

G. The air passes from the nasal passages to the throat, or pharynx.

H. In the back of the throat are two tubes.
1. The gullet, or esophagus, leads to the stomach.
2. The windpipe, or trachea, which is in front of the esophagus, leads to the lungs.

I. At the top of the windpipe is a flap or lid of tissue called the **epiglottis**.
1. The epiglottis covers and closes the windpipe when food and water are being swallowed because otherwise the food and water would go down the windpipe and cause choking.
2. The epiglottis is raised during breathing, and allows air to enter the windpipe freely.

J. At the top of the windpipe is the voice box, or larynx.
1. The voice box is really like a box, and is made of cartilage.
2. The "Adam's apple" is a strip of cartilage that sticks out in front of the voice box.
3. Inside the voice box are two strips of elastic tissue called the **vocal cords**.
4. Tiny muscles can stretch these vocal cords and make them tight.
5. When the vocal cords are tight and air

passes between them, the vocal cords move back and forth quickly, or vibrate.

6. This vibration produces sound.
7. The tighter the vocal cords, the faster the cords vibrate and the higher the sound produced.
8. The looser the vocal cords, the slower they vibrate, and the lower the sound produced.
9. Men have larger voice boxes than women and their vocal cords are longer and thicker, so their vocal cords vibrate more slowly and their voices are lower.

K. The bottom of the windpipe divides into two branches, called **bronchi**, and each branch enters one of the lungs.

L. The bronchi divides into smaller branches called **bronchial tubes.**

M. The bronchial tubes keep branching into smaller and smaller tubes until the smallest tubes end in clusters of little air sacs called **alveoli.**

N. The air sacs look like tiny clusters of grapes, and each lung is one great mass of these clusters of air sacs.

II. How We Breathe

A. Breathing is different from respiration because breathing refers only to the process of getting air containing oxygen into the body and getting air containing carbon dioxide out of the body.

B. Many persons think that in breathing the lungs draw in air, expand, and make the chest bulge, but it is not true.

C. Air is breathed in because it is forced into the lungs because of changes in the size of the chest cavity and changes in the air pressure of the chest cavity.

1. The **diaphragm,** a strong bow-shaped sheet of muscle between the chest and the abdomen, plays an important part in breathing.
2. When muscles in the diaphragm contract, the diaphragm is pulled downward.
3. At the same time the rib muscles contract and lift the ribs upward and outward.
4. The combined action of the diaphragm and ribs increases the size of the chest cavity, and the elastic lungs expand and become larger.
5. This increased size of the lungs reduces the pressure of the air already in the lungs.
6. The air outside the body now has a greater pressure than the air inside the lungs, and so it is pushed into the nose, nasal passages, windpipe, and lungs.

D. Air is breathed out when the chest cavity becomes smaller.

1. The muscles in the diaphragm relax, and the diaphragm moves up again.
2. The muscles in the ribs relax, and the ribs move downward and inward.
3. The chest cavity now becomes smaller, making the lungs smaller, so that air is forced out of the lungs and the body.

E. Breathing is one activity of the body that can take place involuntarily or voluntarily.

F. In involuntary breathing, nerves in the brain control the muscles of the diaphragm and the ribs so that breathing takes place automatically.

III. How Respiration Takes Place

A. The air sacs in the lungs are surrounded by millions of capillaries.

B. The oxygen that comes with the air into the lungs passes through the thin walls of the air sacs and through the thin walls of the capillaries into the blood.

C. Red blood cells pick up the oxygen, and the blood becomes bright red.

D. The blood passes from the lungs to the heart, which pumps the blood through the arteries and capillaries to every part of the body.

E. The cells in the body take the oxygen and use it to burn the digested food, producing heat and energy and giving off carbon dioxide.

F. The red blood cells pick up the carbon

dioxide, and the blood now becomes dark red.

G. The blood passes through the capillaries and veins back to the heart.

H. The veins of the skin appear blue because the skin has a yellow pigment that gives the dark red blood a bluish appearance.

I. The heart sends the blood containing the carbon dioxide to the lungs.

J. In the lungs the carbon dioxide leaves the blood and passes out through the thin walls of the capillaries and through the thin walls of the air sacs into the lungs.

K. The air containing carbon dioxide is forced out of the lungs, and fresh air containing oxygen is forced into the lungs.

L. This action of getting oxygen into the body, using the oxygen to produce heat and energy, and getting the waste carbon dioxide out of the body goes on all the time.

THE EXCRETORY SYSTEM

I. Excretion

A. The removal of waste materials from the body is called **excretion.**

B. The human body produces many different kinds of waste materials.

1. Carbon dioxide, produced by the cells, is a waste material.
2. Excess water in the body is a waste material.
3. The digestive juices left behind after digestion has taken place are waste materials.
4. When cells, tissues, and muscles wear out or break down, mineral salts and nitrogen compounds are formed as waste materials.
5. Undigested and unused food is waste material.

II. How Waste Materials Are Removed

A. The body gets rid of waste materials in different ways.

B. The lungs give off carbon dioxide and some excess water in the form of water vapor.

C. The skin gives off perspiration, which contains water and dissolved mineral salts.

D. The **kidneys** play an important part in the removal of waste materials.

1. The kidneys are two dark red, bean-shaped organs located in the lower part of the back.
2. Each kidney is packed with millions of tiny tubes.
3. These kidney tubes remove from the blood such waste materials as mineral salts and protein compounds.
4. These wastes, together with excess water, form a liquid called **urine.**
5. The urine flows from the kidneys through tubes (ducts) to a storage organ called the **bladder.**

E. The undigested and unused food, together with used digestive juices, pass through the large intestine and out of the body as feces.

THE NERVOUS SYSTEM

I. The Function and Parts of the Nervous System

A. The nervous system has many functions.
1. It controls the action of the muscles and other tissues.
2. It controls the action of the organs.
3. It controls sensations such as smell, taste, touch, pressure, sight, hearing, heat, cold, and pain.
4. It controls thinking, learning, and memory.

B. The central part of the nervous system is made up of the **brain** and **spinal cord.**
1. The brain is located in the skull.
2. The spinal cord lies along almost the whole length of the back.

C. The rest of the nervous system is made up of **nerves,** which spread out from the brain and spinal cord to every part of the body.

II. The Nerves

A. The cells of the nervous system are called **neurons.**

B. These nerve cells are different sizes and shapes, but they all are designed to carry messages, called **nerve impulses,** through the body.

C. Every nerve cell (neuron) has a cell body and many fine threads, called **nerve fibers,** which spread out from the body.
1. One of these nerve fibers, called an **axon,** is very long, and carries messages away from the cell body.
2. All the other nerve fibers, called **dendrites,** are much shorter, and carry messages to the cell body.
3. The axon and dendrites branch many times at their tips, making the tips look like tiny brushes.

D. The bodies of the nerve cells usually lie in the brain and spinal cord, and the nerve fibers run to the head, body, and feet.

E. There are three kinds of neurons (nerve cells): **sensory neurons, motor neurons,** and **associative neurons.**

F. Sensory neurons have to do with feelings or sensations.
1. Their cell bodies usually lie in the brain and spinal cord, and their nerve fibers spread out to sense organs all over the body.
2. The nerve fibers carry messages (nerve impulses) from the sense organs to the cell bodies.

G. Motor neurons have to do with producing motion in the body.
1. Their cell bodies also usually lie in the brain and spinal cord, and their nerve fibers spread out to the muscles, tissues, and organs of the body.
2. The nerve fibers carry messages from the cell bodies to the muscles, tissues, and organs.

H. Associative neurons, sometimes also called **central neurons,** are located between the cell bodies of the sensory and motor neurons.
1. Both the cell bodies and nerve fibers of associative neurons are usually located in the brain and spinal cord.
2. The associative neurons act as "go-betweens" in receiving and sending messages.

I. All three kinds of neurons (nerve cells) are involved in receiving and sending messages (nerve impulses).
1. Nerve fibers in the sense organs all over the body carry messages to the cell bodies of the sensory neurons.
2. The sensory neurons send these messages through nerve fibers to the cell bodies of the associative neurons, which immediately transfer these messages through nerve fibers to the cell bodies of the motor neurons.
3. The cell bodies of the motor neurons then send messages through nerve fibers

to the muscles, tissues, and organs of the body.

J. Bundles of nerve fibers are called **nerves.**
1. In most nerves the fibers carry messages in one direction only.
2. Nerves that only carry messages toward the brain and spinal cord are called **sensory nerves.**
3. Nerves that only carry messages away from the brain and spinal cord are called **motor nerves.**
4. A few nerves, called **mixed nerves,** can carry messages both toward and away from the brain and spinal cord.

III. The Brain

A. The brain, located inside the skull, is perhaps the most highly specialized organ in the human body.

B. It has a wrinkled appearance because its surface is folded many times.

C. It is the control center of the body, receiving messages from all parts of the body and sending out orders in return.

D. There are three main parts to the brain: the **cerebrum,** the **cerebellum,** and the **medulla.**

E. The cerebrum is the largest part of the brain.
1. It is made up of two halves that are firmly joined together.
2. The cerebrum has many functions.
3. It is the part of the brain that controls thinking, reasoning, learning, memory, and imagination.
4. It receives messages from the sense organs and recognizes them as smell, taste, touch, pressure, sight, hearing, heat, cold, and pain.
5. It also controls the voluntary movement of the muscles in the body.
6. The left side of the cerebrum controls movement of the right side of the body, and the right side of the cerebrum controls movement of the left side of the body.

F. The much smaller cerebellum is located below and behind the cerebrum.
1. It coordinates the movements of the muscles so that they operate together smoothly, as in walking.
2. It also helps the body keep its sense of balance.

G. The medulla is located at the bottom of the brain, and joins the top of the spinal cord.
1. It controls the operation of the involuntary muscles in the body.
2. This operation means that it also controls such vital functions as heart action, breathing, digestion, coughing, and sneezing.

IV. The Spinal Cord

A. The spinal cord is a long rod of nerve tissue going down almost the whole length of the backbone.

B. It connects with the medulla of the brain through a large hole in the base of the skull.

C. Thirty-one pairs of nerves branch off the spinal cord and connect the brain with the rest of the body.

D. If the spinal cord should be cut, all the nerves below the point where the cut was made would not operate, and all the parts of the body controlled by these nerves would be paralyzed.

V. Reflex Action

A. An action of the body that takes place automatically without thinking is called a **reflex action.**

B. The reflex action takes place before the brain has had time to learn about the action.

C. In most reflex actions the messages (nerve impulses) usually travel only to the spinal cord and back.

D. An example of a simple reflex action is the behavior that takes place when a per-

son touches something hot and burns his fingers.

1. The person pulls his fingers away almost immediately, even before he feels the pain.
2. This action occurs because the skin sends a message to sensory nerve cells in the spinal cord.
3. The sensory nerve cells transfer the message to nearby associative nerve cells, which then transfer the message to motor nerve cells.
4. The motor nerve cells now send a message to the muscles in the person's arm, and the muscles contract, pulling the arm and fingers away.
5. Meanwhile the spinal cord also sends a message to the brain, which then recognizes the sensations of both heat and pain.
6. The extra time saved by the reflex action, which takes place before the brain is able to learn what is happening, prevents the finger from becoming badly burned.

E. Other examples of reflex action include jumping when frightened, blinking the eyes when objects suddenly come near them, and laughing when tickled.

F. The medulla of the brain controls such reflex actions as swallowing, coughing, and sneezing.

THE SENSE ORGANS

I. The Special Senses of Man

A. The nervous system makes it possible for the human body to have many sensations.

B. Different sensory nerves located in special sense organs send nerve impulses (messages to the brain, which recognizes these impulses as sensations.

C. These sensations include touch, pressure, heat, cold, pain, smell, taste, sight, hearing, and balance.

D. All these sensations come from five sense organs: the **skin, nose, tongue, eyes,** and **ears.**

II. The Skin

A. The skin has five different kinds of sensory nerve endings, each responsible for a different kind of sensation.

B. These sensations are touch, pressure, heat, cold, and pain.

C. Each kind of nerve ending can produce only one special sensation.

D. The sensory nerves are not spread out evenly over the skin.

1. As a result, the skin is more sensitive in some parts than in others.
2. The fingertips and the forehead have a great many nerve endings that are sensitive to touch.

E. The nerve endings sensitive to touch are very near the surface of the skin, but the nerve endings sensitive to pressure are located deeper inside the skin.

III. The Nose

A. The sense of smell is located in the nose.

B. Nerve endings in the nose are sensitive to chemicals in the air that are breathed in.

C. These chemicals then dissolve in the liquid (mucus) that covers the lining of the nasal passages.

D. When the nose smells the same odor for a long time, the nerve endings become deadened to that particular odor, and then there is no more sensation of smell for that odor.

E. Man's sense of smell is poor compared to many animals, such as the deer and the dog.

IV. The Tongue

A. The sensation of taste is located in clusters of cells, called **taste buds**, that are spread unevenly over the tongue.
   1. Inside these cells are nerve endings that are sensitive to taste.
   2. The taste comes from chemicals in the food, which must first be dissolved in the saliva before the taste can be sensed.

B. The taste buds can recognize only four flavors: sweet, sour, salty, and bitter.
   1. The taste buds at the tip of the tongue are sensitive to sweet and salty flavors.
   2. The taste buds along the sides of the tongue are sensitive to sour flavors.
   3. The taste buds at the back of the tongue are sensitive to bitter flavors.
   4. Many foods have more than one flavor in them.

C. Much of what we think is taste is really smell.
   1. While the food is being chewed, odors are given off that enter the nasal passages and reach the nerve endings sensitive to smell.
   2. The combination of both taste and smell gives the food its complete flavor.

V. The Eye

A. The sense of sight is located in the eye.

B. The bones of the skull protect the eyes on all sides except the front.

C. The **eyelids** have two main functions.
   1. They close, or blink, to protect the front of the eye.
   2. They help spread a watery liquid across the surface of the eye that keeps the eye surface moist, protects the eyes against germs, and washes out dirt.
   3. When drops of this watery liquid come out of the eye, they are called **tears.**

D. The complete eye is shaped like a ball, and is called the **eyeball.**

E. Most of the eyeball has a tight, white cover around it, and the part that we can see is called the white of the eye.

F. A small part of this cover, called the **cornea,** is transparent so that light can pass through it.

G. The cornea covers a dark opening in the eye, called the **pupil.**
   1. The pupil allows light to go into the eyeball.
   2. The pupil appears to be black because the inside of the eyeball is dark.

H. The colored circle around the pupil is called the **iris.**
   1. The iris protects the eye by controlling the amount of light that enters the eyeball.
   2. Muscles in the iris change the size of the pupil, depending upon how strong the light is that strikes the eye.
   3. When the light is bright, the iris becomes bigger, which makes the pupil smaller and cuts down the amount of light entering the eyeball.
   4. When the light is dim, the iris becomes narrower which makes the pupil larger and allows more light to enter the eyeball.

I. Inside the eyeball is a convex **lens,** which is thick in the middle and thin at the ends, and two liquids.
   1. The watery liquid in front of the lens is called the **aqueous humor.**
   2. The jellylike liquid behind the lens is called the **vitreous humor.**
   3. The lens, with the help of the two liquids, bends the rays of light as they enter the eyeball and makes the rays of light come together.

J. At the back of the eyeball is a sensitive lining, called the **retina.**
   1. The rays of light entering the eyeball are bent by the lens and come together, or focus, at the retina.
   2. The retina has tiny, sensitive nerve endings, leading to the **optic nerve.**
   3. When light strikes the retina, the tiny nerves send impulses (messages) through the optic nerve to the brain, where we experience the sensation of sight.

K. There are two kinds of nerve cells in the retina: the **cones** and the **rods**.
   1. The cones help us see objects that are in bright light, and help us recognize different colors.
   2. The rods help us see objects that are in dim light.
   3. Many animals see better than man at night because there are more rods in their retinas.

L. Muscles attached to the lens can make the lens thinner or thicker.
   1. These muscles allow the rays of light reflected from objects to come together, or focus, at the retina.
   2. When an object is far away, the lens becomes thinner because the rays of light from the distant object do not have to be bent very much to focus at the retina.
   3. When an object is near, the lens becomes thicker because the rays of light from the close-by object must be bent very much to focus on the retina.

M. Because the lens of the eye is a convex lens, the image formed on the retina is upside down.
   1. Yet, in some way that scientists do not know, the brain turns this message right side up.
   2. Also, because we have two eyes, we get two images, which the brain is able to put together to get only one image.

N. The eye is able to see an object for a little while after the light from the object has stopped entering the eye.
   1. This effect is called **persistence of vision.**
   2. Motion pictures use persistence of vision to give still pictures the effect of motion.
   3. A series of still pictures, each a little different from the other, is shown on a screen so quickly that we continue to see one picture while the next is being shown.
   4. This persistence of vision makes the pictures blend together in the eye and gives the impression of movement.

VI. Defects of the Eye

A. Many persons suffer from defects of the eye, and cannot see properly.
   1. Four common defects of the eye are: **nearsightedness, farsightedness, astigmatism,** and **color blindness.**
   2. All these defects except color blindness can be corrected with the help of eye glasses.

B. In nearsightedness, nearby objects can be seen clearly, but distant objects seem blurred and fuzzy.
   1. Nearsightedness occurs if the eyeball is too long, or if the eye muscles make the lens too thick, so that the rays of light come together, or focus, in front of the retina.
   2. Nearsightedness is corrected by glasses with concave lenses, which spread the rays of light before they enter the eye; in this way the rays come together farther back and form sharp, clear images on the retina.

C. In farsightedness, distant objects can be seen closely, but nearby objects seem blurred and fuzzy.
   1. Farsightedness occurs if the eyeball is too short, or if the eye muscles do not make the lens thick enough, so that the rays of light still have not come together when they reach the retina.
   2. Farsightedness is corrected by glasses with convex lenses, which bend the rays of light inward before they enter the eye, and in this way let the rays come together sooner and form sharp, clear images on the retina.

D. In astigmatism, lines running in one direction may seem clear, but lines running in another direction may seem blurred.
   1. Astigmatism occurs if the cornea or the lens is not curved properly; this defect makes the lines curve either too much or too little in one direction.
   2. Astigmatism is corrected by glasses with specially ground lenses, which have

exactly the opposite curve to the defect in the cornea or lens.

E. In color blindness, the eye is unable to recognize colors, especially red and green, so that they seem different.
   1. Color blindness occurs if the retina does not have enough cones, or if the cones are defective.
   2. Scientists do not know of any way to correct color blindness.

VII. The Ear

A. The sense of hearing is located in the ear.

B. There are three parts to the ear: **the outer ear**, **the middle ear**, and the **inner ear.**

C. The outer ear collects the sound waves and sends them through a tube to the middle ear.
   1. A thin piece of tissue (membrane), commonly called the **eardrum,** is stretched across the end of the tube.
   2. When sound waves strike the eardrum, they make it move back and forth rapidly, or vibrate.
   3. The higher the sounds, the faster the eardrum will vibrate.
   4. The louder the sounds, the more strongly the eardrum will vibrate.

D. The middle ear passes the vibrations of the eardrum to the inner ear.
   1. The middle ear has three small bones that are joined together, and are called the **hammer, anvil,** and **stirrup.**
   2. The first bone, the hammer, is connected to the eardrum.
   3. The third bone, the stirrup, is connected to the membrane of the inner ear.
   4. As the eardrum vibrates, all three bones vibrate and make the membrane of the inner ear vibrate.

E. The hearing part of the inner ear is a spiral passage, called the **cochlea,** shaped like a snail's shell and filled with a liquid.
   1. Inside the liquid, attached to the spiral passage, are thousands of tiny nerve endings.
   2. When the membrane of the inner ear vibrates, the liquid inside the spiral passage begins to vibrate.
   3. The tiny nerve endings receive the vibrations of the liquid and send nerve impulses (messages) to the **auditory nerve.**
   4. The auditory nerve carries these nerve impulses to the brain, where we get the sensation of sound.

F. The ear also helps control our sense of balance.
   1. The inner ear also contains three tubes that curve around in half circles, and are called the **semicircular canals.**
   2. The semicircular canals are laid out in the three different directions that the head can move: up and down, sideways, and turning.
   3. The canals are filled with a watery liquid that moves every time the head moves.
   4. Nerve endings line the walls of the canals, and, when the head moves, the liquid in one of the canals rushes to one end and presses on the nerve endings.
   5. This pressure on the nerve endings causes nerve impulses (messages) to travel through a branch of the auditory nerve to the cerebellum of the brain.
   6. The cerebellum then sends a message to the muscles which help us keep our balance.
   7. Any whirling movement, or a steady up and down movement like that produced in a boat, makes the liquid in the canals move continuously from one side to the other, and causes dizziness and sometimes a feeling of nausea.

THE ENDOCRINE SYSTEM

I. The Ductless Glands

A. **Glands** are organs whose cells give off juices that have special uses in the body.

B. There are two kinds of glands: glands with ducts (tubes) and glands without ducts.

C. Glands with ducts are called **duct glands,** and give off juices that travel through the ducts or tubes to the parts of the body they affect.

1. Examples of duct glands are the salivary glands in the mouth, and the sweat and oil glands in the skin.
2. The digestive juices that help digest food in the body are given off by duct glands in the stomach, the intestine, the pancreas, and the liver.

D. Glands without ducts are called **ductless glands,** and also **endocrine glands.**

1. These glands give off juices containing chemicals called **hormones.**
2. The hormones pass directly through the walls of the capillaries (tiny blood vessels) into the blood and travel to different parts of the body.
3. Their function is to regulate the body activities.
4. Some hormones affect every part of the body, but others affect only certain parts or organs.

E. The six most common ductless or endocrine glands in the body are the **pituitary gland,** the **thyroid gland,** the **parathyroid glands,** the **Islands of Langerhans** in the pancreas, the **adrenal glands,** and the **reproductive glands.**

II. The Pituitary Gland

A. The pituitary gland is a very tiny gland, about the size of a cherry, attached to the bottom of the brain.

B. It gives off at least 10 different hormones.

1. Some of these hormones affect or regulate the activity of almost all the other ductless glands.
2. Other hormones affect the activity of the kidneys, blood vessels, and milk-producing glands.

C. One hormone, commonly called the **growth hormone,** regulates the growth of the skeleton and the body.

1. If the pituitary gland is overactive during childhood and gives off too much of this growth hormone, the child will grow up to be a giant.
2. If the pituitary gland is overactive in an adult, the adult's jaws, nose, hands, and fingers will become very large.
3. If the pituitary gland is underactive during childhood and does not give off enough of this growth hormone, the child will become a midget.

D. Because the pituitary gland controls the activity of almost all the other ductless glands, it is often called the "master gland" of the body.

III. The Thyroid Gland

A. The thyroid looks like a big butterfly with its wings spread out, and is located below the voice box on the windpipe.

B. It gives off a hormone, called **thyroxin,** which controls the speed or rate at which the body burns and uses food.

1. The thyroxin has iodine in it.
2. A lack of iodine in the diet will make the thyroid gland swell and the throat bulge out to form a **goiter.**
3. In those parts of the country where there is little iodine in the soil and in the food, specially prepared iodized salt is used to give the thyroid gland the iodine it needs.

C. If the thyroid gland is overactive, making the cells in the body speed up their activities, a person will become restless, nervous, and easily excited.

1. His heart will beat faster and his hands may shake.
2. Although he eats a lot, he will not get fat, and may even lose weight.
3. Doctors correct this overactivity by cutting out some of the thyroid gland.

D. If the thyroid gland is not active enough, a person will not have any energy.

1. The cells in the body slow down their activities.
2. The person may not eat much, but he will still gain weight.
3. Doctors correct this underactivity by giving the person pills with thyroxin in them.

E. If a baby's thyroid gland is underactive, and the situation is not corrected in time, the child will become a feebleminded dwarf.

IV. The Parathyroid Glands

A. The parathyroid glands are four small glands located on the back of the thyroid gland.

B. They give off a hormone, called **parathormone**, which controls the use of calcium in the body.

C. Too much of this hormone in the body takes calcium from the bones, making the bones soft.

D. Too little of this hormone in the body causes painful muscle cramps.

V. The Islands of Langerhans

A. The pancreas is both a duct gland and a ductless gland, and is located just behind the stomach.

B. As a duct gland it gives off pancreatic juice, which helps in the digestion of food in the small intestine.

C. Scattered throughout the pancreas are small groups of cells called the Islands of Langerhans, which are ductless glands and give off a hormone called **insulin.**

D. Insulin regulates the use and storage of sugar in the body.

1. When the body digests food, the carbohydrates are broken down into simple sugars, especially one simple sugar called **glucose.**
2. The cells in the body use oxygen to burn some of this glucose, producing heat and energy.
3. Whatever glucose the body does not use at the moment is stored in the liver until needed by the cells.

E. When the pancreas does not produce enough insulin, a person develops a sickness called **diabetes.**

1. The liver cannot now store the sugar, and the cells cannot use it efficiently.
2. The muscles and tissues cannot get the sugar they need, and the blood becomes flooded with sugar.
3. The person loses weight, urinates very often, and is very thirsty.
4. Some of the excess sugar in the blood passes out through the urine.
5. Persons with diabetes are given regular injections of insulin, and are also put on a controlled diet.

VI. The Adrenal Glands

A. The adrenal glands are two small glands located on top of the kidneys.

B. The outer layer of the adrenal glands gives off many hormones, which control the digestion of food and regulate the balance of salt and water in the body.

C. The inner layer gives off a hormone called **adrenalin.**

1. When a person becomes angry or frightened, the adrenal glands pour large amounts of adrenalin freely and quickly into the blood.
2. The adrenalin makes the heart beat faster, blood pressure rise, digestion slow down, breathing become faster and deeper, and causes the liver to send more of its stored sugar to the blood.
3. Adrenalin also makes blood clot more easily and quickly.
4. When doctors are afraid the heart may

stop beating, they give the patient adrenalin.

5. Sometimes adrenalin is used in asthma attacks because it makes the small air tubes in the lungs open wider, and in this way breathing is helped.

VII. The Reproductive Glands

A. The sex organs give off a number of hormones, commonly called sex hormones.

B. These hormones have to do with giving the human body its special appearance and characteristics.

C. Sex hormones give males deep voices, large muscular chests, narrow hips, beards, and body hair.

D. Sex hormones give females their characteristic high voices, rounded bodies, greater amount of fat under the skin, development of breasts, sparse body hair, and menstruation.

LEARNING ACTIVITIES FOR "THE HUMAN BODY"

THE MAKEUP OF THE HUMAN BODY

1. *Examine body cells* · Repeat Learning Activity 1 of "Composition and Classification of Animals," Chapter 14 (p. 540), examining cells obtained from inside of your cheek.

2. *Examine different cells and tissues* · Repeat Learning Activity 2 of "Composition and Classification of Animals," Chapter 14 (p. 540), examining and comparing small amounts of steak, bones, nerves, blood, and other tissue under the microscope.

3. *Identify body organs* · Obtain a chart or model of the human body, and locate such key organs as the heart, liver, stomach, intestines, kidneys, lungs, eyes, ears, and brain. Discuss the basic functions of each organ, and point out that each organ is made up of a group of tissues working together.

4. *Identify the body systems* · By using a chart or model of the human body, identify the 10 large body systems and discuss the basic function of each. List the organs that make up each system.

THE SKIN

1. *Cross section of the skin* · Obtain a chart or draw a diagram showing a cross-section of the skin. Distinguish between the dermis and epidermis. Note the presence of nerves and blood vessels, and locate the oil and sweat glands. Discuss the function of each constituent of the skin.

2. *Make fingerprints* · Have the children make and compare fingerprints. Obtain an ink stamp pad. Let each child pick up ink on his right forefinger by pressing the right side of his finger tip against the pad and rolling the finger from right to left. Then have the child roll the inked finger tip from right to left on a small piece of white paper with the child's name on it. Let the children compare fingerprints, using a magnifying glass, and note that no two prints are the same.

3. *Examine human hair* · Study differently colored human hairs under the microscope. See if you can find three layers of cells. The middle layer is the one that contains the color. Note any difference in appearance and quality of the hairs.

4. *Measure the rate of growth of nails* · Place a tiny drop of dilute nitric acid close to the base of one fingernail and one toenail. The nitric acid will produce a permanent yellow stain on the nail. Measure the distance between the edge of each nail and the nitric acid spot. Repeat the measurement each week until the yellow spot is cut off. Determine and compare the rate of growth of each nail.

5. *The skin helps regulate body temperature* · Wet the end of your finger and blow on it. The finger feels cool as the moisture evaporates, heat energy being taken away from the finger to produce the evaporation. Point out that the evaporation of perspiration produces the same cooling effect.

Have the children recall how flushed their faces become when they are hot. Point out that this flushing occurs because the blood vessels expand and allow more of the heated blood to flow into the skin. Now have the children recall the "goose bumps" that formed on their arms when they became cold. These bumps occur because the blood vessels contract and the pores close tightly to prevent body heat from escaping. As a result, tiny bumps are formed all over the surface of the skin.

6. *Oil glands* · Have the children rub one finger along the side of the nose, and then rub this finger against the other fingers. They will feel the oil that the first finger picked up from the skin. Rub a cleansing tissue along the side of the nose and see the stain produced by the oil.

THE SKELETAL SYSTEM

1. *The skeleton* · Obtain a model or chart of the human skeleton. Examine the skull, spinal column, breastbone, ribs, pelvis, collarbones, arms, and legs. Observe how the bones of the skull have become firmly united, forming an immovable joint. Note the ball-and-socket joints in the shoulder and hip, and the hinge joints in the elbow and knee. There are also movable joints in the spinal column, the fingers, and the toes. Point out that the bones of the joints are bound together by ligaments.

2. *Examine an animal bone* · If possible, obtain the leg bone of a lamb, calf, or pig from the meat market. Ask for a bone that has the end of a joint still on it, and have the bone split lengthwise in half. Examine the joint and distinguish between the cartilage and the bone. Identify the ligaments holding the joint together. Look for bits of tendon tissue that served to hold the muscles to the bone. Locate the yellow, fatty marrow in the center of the long part of the bone.

3. *The composition of bone* · Place a chicken bone in a metal pie plate and heat the tin over a Bunsen burner or in the oven until the bone is covered with a grayish-white ash. Let the bone cool, and then note how light and brittle the bone now is. Point out that the heat burned away all the animal matter in the bone, leaving the mineral matter behind. If you have an accurate balance, weigh the bone before and after heating, and determine the percentages of animal and mineral matter in the bone.

Soak the leg or thigh bone from a chicken in a jar of strong vinegar for 4 or 5 days. Remove the bone and wash it in water. Now bend the bone. The vinegar has dissolved and removed the mineral matter from the bone, leaving the soft, flexible animal matter behind. Although the bone still has its original shape and appearance, it will now be soft and flexible enough so that you can very easily tie it into a knot.

4. *Examine a ligament* · Obtain the joint from a calf, lamb, or pig shoulder from the meat market. Move the joint and examine the ligament that holds the ends of the bones together.

5. *Examine X-rays of broken bones* · Obtain X-rays of broken bones and point out the different kinds of breaks. Point out the need for a cast or splints in helping a broken bone to mend. Discuss what might happen if an un-

qualified person moves somebody who may have broken some bones in an accident.

THE MUSCULAR SYSTEM

1. *The muscles of the body* · Obtain a chart of the muscular system and examine the arrangement of the muscles. Identify the large muscles that move the head, shoulders, torso, arms, and legs. Note that most of the muscles are connected to the bones either directly or by tendons.

2. *Examine a frog's muscles* · Obtain a freshly killed or preserved frog and carefully remove the skin. Examine the bands of muscles that make up the frog's muscular system. Observe the powerful hind leg muscles closely and see how they operate.

3. *Locate body tendons* · Move the fingers of both hands up and down rapidly, just as if you were playing the piano. Notice the movement of the tendons on the back of your hand. The tendons are being moved by muscles in your forearm. Continue the movement for a full minute or two, and you will feel the forearm muscles becoming tired.

Place the fingers of your left hand on the inside of the elbow of your right hand, just above the joint, and flex your right forearm a few times. You will feel the tendons moving. Grasp the back of one ankle and move your foot up and down. The large tendon that you feel moving is the Achilles tendon.

4. *Observe the tendons of a chicken's foot* · Obtain a chicken's foot from the meat market. Cut away some of the skin and flesh to expose the strong, white tendons. Pull the tendons one at a time. Some tendons will make the toes bend whereas others will straighten the toes. Because the tendons are attached to muscles, note that the muscles only pull, and never push, regardless of how the toes move.

5. *How voluntary muscles work* · Double your arm and feel the "muscle" you make. This "muscle" is the biceps muscle. Now grasp the outside of your upper arm near the elbow and straighten your arm. You will feel the pull of your triceps muscle. Note that muscles work in pairs. When you bend your arm, the biceps muscle contracts while the triceps muscle relaxes. When you straighten your arm, the biceps muscle relaxes and the triceps muscle contracts. Point out that when a muscle contracts, it becomes shorter and thicker, producing a pull on the bones.

Grip the back of your thigh and bend your leg at the knee, bringing your heel up toward the thigh. Note how the thigh muscle thickens as it contracts and pulls on the bone.

6. *The action of involuntary muscles* · Look in a mirror and watch your eyelid close automatically. This demonstration shows that involuntary muscles are working. Now use voluntary muscles to close the eyelid yourself. This condition is also true of the movement of your diaphragm. Note how involuntary muscles make the diaphragm move automatically as you breathe. Now use voluntary muscles to raise and lower the diaphragm muscles yourself.

7. *The action of the lip muscles* · Purse your lips tightly, just as if you were going to whistle, and feel the ring of muscles around the lips. Point out that these lip muscles are unusual in that they are attached to other muscles rather than to tendons or bones.

FOOD

1. *Test foods for the presence of simple sugars* · Obtain some Benedict's solution from the drugstore. Pour 1 teaspoon of corn syrup into a Pyrex test tube. Add a few drops of the Benedict's solution and heat the test tube gently over the flame of a Bunsen burner or an alcohol lamp, making sure to point the mouth of the test tube away from yourself and the children. The color of the blue solution will change first to a yellow-green and then to a

brick red color, showing the presence of simple sugars.

Repeat the test, using different fruit juices. Try using small amounts of solid foods, including soda crackers or saltines, raisins, and a bit of onion. The children will be surprised to learn that the onion is rich in simple sugars.

2. *Test foods for the presence of starch* · Place a small amount of corn starch in a test tube half-filled with water. Add one or two drops of tincture of iodine to the solution and stir. A blue-black color will form, showing the presence of starch. Place a drop or two of the iodine on a slice of raw potato and a slice of bread. The blue-black color will again show the presence of starch. Repeat the test, using a variety of both starchy and nonstarchy foods, such as soda crackers or saltines, boiled macaroni or spaghetti, boiled rice, a lump of table sugar, cooked egg white, cheese, bacon, and meat.

3. *Test foods for the presence of fats* · Rub a bit of butter on a piece of brown paper bag, and warm the paper gently over a hot plate. Put two or three drops of water on a second piece of brown paper. Now hold both pieces of paper up to sunlight or a bright light. Both spots will be translucent and allow light to pass through. However, the water spot will become dry and stop being translucent, but the "grease" spot will continue to be translucent.

Try this test for the presence of fats with such foods as bacon, nuts, the white and the yolk of a boiled egg, olive oil, mayonnaise, beef, bread, and leafy vegetables. Note which foods produce a permanent grease spot on the brown paper.

4. *Test foods for the presence of proteins* · Place a small piece of the white of a boiled egg in a test tube. Add enough nitric acid to cover the piece of egg white. Heat the test tube gently over the flame of a Bunsen burner or alcohol lamp, shaking the test tube to keep the egg white moving, *and at the same time keeping the mouth of the test tube pointed away from yourself and the children.* Remove the test tube as soon as the nitric acid begins to boil. Pour off the nitric acid into the sink and let the cold water run for a little while to wash down all the acid. Note that the egg white has turned yellow. Now pour a little ammonia into the test tube. An orange color will form on the egg white, showing the presence of proteins. Repeat the test, using a variety of foods, such as bread, cheese, boiled spaghetti or macaroni, lean meat, and lima beans.

5. *Test foods for the presence of minerals* · Place a small piece of bread on an old spoon and, holding the spoon with an asbestos mitt, heat the spoon strongly over a Bunsen burner flame. The bread will burn, turn black, and finally become a small amount of grey-white ash. This ash shows the presence of minerals. Repeat the test, using a variety of foods.

6. *Test foods for the presence of water* · Place a few small pieces of bread in a dry test tube and heat the tube gently over the flame of a Bunsen burner or alcohol lamp. Tiny droplets of water will appear on the upper part of the test tube. The water was driven out of the heated bread in the form of steam, and then it condensed on the cool upper part of the test tube. Repeat the test, using a variety of foods.

7. *The vitamin content of foods* · Have the children make a chart listing foods that are good sources of the various vitamins. Let them check the foods in their daily diets to see if they appear on the chart. Have the children read and report on the diseases caused by vitamin deficiencies.

8. *Foods release heat energy when digested* · Put one end of a straightened paper clip through a peanut, brazil nut, or cashew and apply a lighted match to the nut. The nut will burn, giving off heat energy. Pour some melted butter or cooking oil into a small saucer and place a piece of soft string in the butter or oil,

with one end of the string protruding above the liquid and hanging over the side of the saucer. After the string has become saturated with the butter or oil, apply a lighted match to the end of the string. The string will act as a wick, and the butter or oil will burn for some time. Point out that when foods are digested in the body, they give off heat energy.

9. *The Calorie value of food* · Have the children keep an accurate record of what they have eaten each day for a week, being quite specific about the size of the portions and the number of helpings. Remind the children to include whatever they ate between meals. Have them consult a chart of the Calorie values for common foods, find out how many Calories they took in each day, and then take an average for the week. Let them compare their average daily Calorie intake with the value suggested in the Calorie chart. (Most large life insurance companies have booklets available including Calorie charts and other pertinent information.)

10. *The four basic food groups* · Have the children keep a record of what they have eaten each day for a week, as described in Learning Activity 9 above. At the end of the week let the children check each day's diet to see if all four basic food groups were represented and if the recommended number of servings for each group has been consumed.

THE DIGESTIVE SYSTEM

1. *The parts of the digestive system* · Obtain a chart or model that shows the body cavity with all the digestive organs in place. Note how the gullet, stomach, small intestine, and large intestine form one long, continuous tube. Locate and identify the liver, pancreas, and gall bladder.

2. *The teeth* · Draw a diagram showing the number of teeth that should be in the mouth, using a U-shape to represent the jaw (Figure 15–1). Have the children examine their teeth with a regular or magnifying mirror and note which of these permanent teeth they already have. They can also note which teeth are perfect, have fillings, have been extracted, or have not yet appeared.

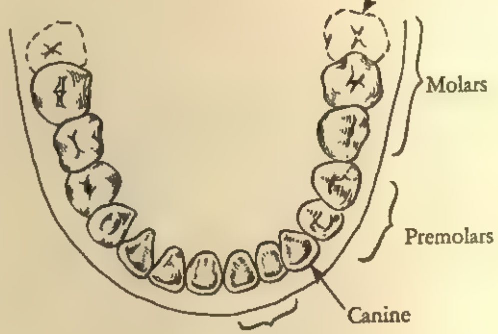


FIGURE 15–1.
DIAGRAM OF THE TEETH IN A JAW

Draw a diagram showing the parts and structure of a tooth, and discuss the proper method for brushing teeth.

3. *Saliva changes starch to sugar* · The children will have discovered in Learning Activities 1 and 2 of "Food" (p. 589) that starch, but little or no sugar, is present in most soda crackers or saltines. Have the children chew a soda cracker or saltine and note how the cracker tastes sweeter after it has been chewed for some time and the saliva has had a chance to act on the starch in the cracker. Place some of this chewed cracker-saliva mixture in a test tube and test with Benedict's solution for the presence of simple sugars, as described in Learning Activity 1 of "Food." As a control, test some saliva alone for the presence of simple sugars.

4. *The digestion of food* · Obtain or draw a chart showing all the organs of the digestive system. Have the children trace the digestion

of a ham sandwich (which contains carbohydrates, fats, and proteins) from the time it enters the mouth until the waste products leave the body. Describe the function of each organ in acting upon and digesting the contents of the sandwich.

THE CIRCULATORY SYSTEM

1. *Examine blood* · Wash your hands thoroughly and then rub a piece of cotton dipped in alcohol over one fingertip. Prick the fingertip with a sterilized needle and squeeze out a drop of blood. Press the blood against a clean microscope slide and cover with a cover glass. Observe the blood under the high power of a microscope. You will see many disc-shaped red blood cells and perhaps one or two of the larger white cells. Note that the red blood cells have no nucleus. Discuss the functions of the red cells, white cells, and platelets in the blood.

2. *Blood clotting* · Discuss the role of the platelets in the clotting of blood. Have the children read about and report on hemophilia, including its inherited occurrence in the royal families of Russia and Spain.

3. *Blood types* · Have the children read about and report on the grouping of blood into four common types, and also on the grouping of blood according to whether or not it possesses the Rh factor. Let the children find out from their parents what type blood they have, and list on the chalkboard the prevalence of each type. Discuss the importance of giving the proper blood type for transfusions.

4. *Observe blood vessels* · Repeat that portion of Learning Activity 2 of "Animals with Backbones," Chapter 14 (p. 549) that deals with observing the arteries, veins, and capillaries in the tail of a fish. Note the movement of the corpuscles through the blood vessels.

5. *Valves in the veins* · Let your arm hang down until the large veins on the back of your hand become swollen and quite visible. Make a fist, place a fingertip on one vein, and push firmly downward toward the knuckles. While holding the finger in place, note how smooth the vein becomes as your finger presses on the valve and prevents blood from flowing into that portion of the vein. Now take away your finger. The vein will fill up with blood again.

6. *Examine an animal heart* · Obtain the heart of a calf, sheep, or pig from the meat market. Pare away any fatty material present, and note how muscular the heart walls are. Try to identify the ventricles and auricles before you begin to cut the heart open. Make incisions on either side of the lower narrow end of the wall. When you enter the ventricle, cut away more material so that you may see the cavities more clearly. Note how thick the walls are, especially those of the left ventricle.

Use a probe to find the main artery leading from the left ventricle to the body and the pulmonary artery leading from the right ventricle to the lungs. Also, probe for the flabbier veins entering the right and left auricles. Look for the valves between the auricles and ventricles. Also, slit the artery walls lengthwise and look for the valves that prevent blood from flowing back into the heart.

7. *Make a stethoscope* · Make a stethoscope from three funnels, a glass Y-tube or T-tube, and two long plus one short pieces of rubber tubing (Figure 15–2). Let the children take turns listening to heartbeats. Compare the heartbeats of the children when they are quiet with their heartbeats after they have jumped up and down 15 to 20 times or exercised vigorously.

8. *Measure pulse beat* · By using the first two fingers of your right hand, feel for the pulse on your left hand at the base of the thumb where the left hand joins the wrist (Figure 15–3). Count the number of pulse beats in 1 minute. Now jump up and down 15 to 20 times, or exercise vigorously, and take your pulse beat for 1 minute again. Note how

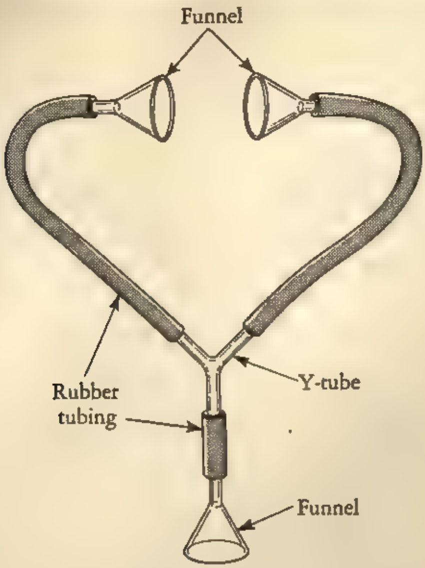


FIGURE 15–2.
A HOMEMADE STETHOSCOPE.

much stronger and faster the pulse beat becomes.

9. *Trace the circulation of blood* · Obtain a chart or draw a diagram of the human circulatory system. Trace the circulation of an imaginary bubble of blood through the body. First have the blood leave the heart, travel through the body to the legs, and then return to the heart. Then have the blood go to the lungs and back. Follow the movement of the blood through the different auricles and ventricles of the heart.

FIGURE 15–3.
TAKING A PULSE BEAT.

10. *The lymph* · Have the children recall the clear liquid that came out of blisters or that oozed over the surface of a skinned knee or elbow. Point out that this clear liquid is lymph. Discuss the function of lymph and lymph nodes.

THE RESPIRATORY SYSTEM

1. *The parts of the respiratory system* · Obtain a chart or draw a diagram of the respiratory system. Locate and identify the nose, nasal passages, pharynx, trachea, larynx, bronchi, bronchial tubes, and lungs. Discuss the function of each of these parts in the process of respiration.

2. *Examine animal lung tissue* · Obtain a portion of the lung of a calf, sheep, or pig from the meat market. Note how spongy the lung tissue is. Examine a section of this lung tissue under the low power of a microscope and locate a cluster of the many air sacs that are found throughout the tissue. Note that each air sac is surrounded by a fleshy wall. Change to the high power of the microscope, and you will be able to see capillaries in the wall.

3. *How we breathe* · Obtain a lamp chimney and a one-hole rubber stopper to fit the narrower top opening of the chimney. Insert a piece of glass tubing through the hole of the stopper. Use a rubber band to fasten a small rubber balloon to the bottom end of the glass tubing, and then insert the stopper into the top of the chimney (Figure 15–4). Cut a piece of rubber from a large rubber balloon and use a rubber band to fasten this piece of rubber firmly to the bottom opening of the chimney.

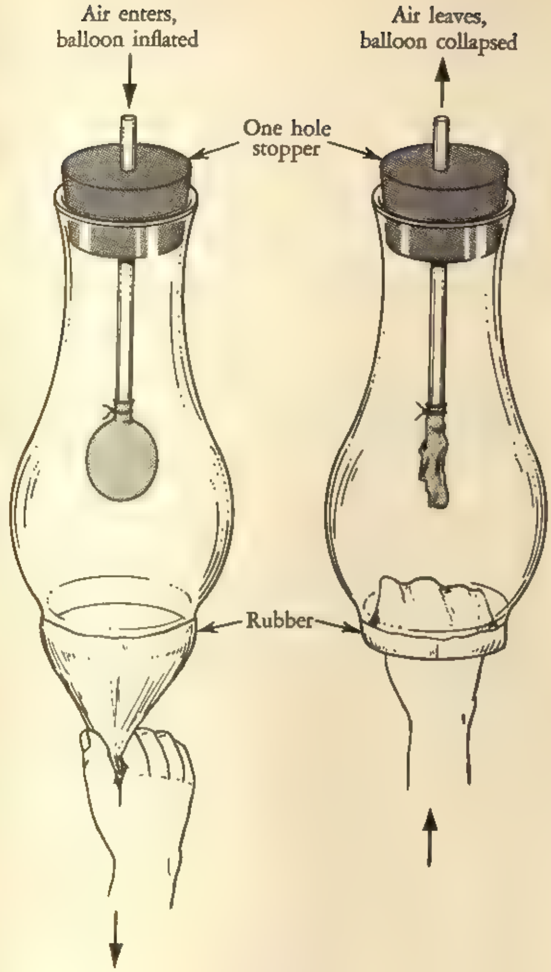


FIGURE 15–4.
THE OPERATION OF THE DIAPHRAGM AND LUNGS DURING BREATHING.

The chimney will represent the chest cavity, the balloon will represent one of your lungs, and the large piece of rubber will represent your diaphragm.

Pull the piece of rubber (diaphragm) downward. The air in the chimney (chest cavity) expands, reducing the air pressure in the chimney. Air from outside the chimney is forced in, inflating the balloon (lung). Now push the piece of rubber (diaphragm) upward. The air in the chimney (chest cavity) is compressed and contracts, increasing the air pressure in the chimney. Air will be forced out of the chimney through the glass tubing, causing the balloon (lung) to deflate. Repeat this procedure several times to simulate the steady action of inhaling and exhaling.

4. *The effect of exercise on the rate of breathing* · Have one child place his hand lightly on another child's chest and count the number of times the child is breathing in 1 minute. Let one inhalation and one exhalation together count as just one breath. Now have the second child jump up and down or exercise until he is breathing quite heavily, and then let the first child count the number of breaths in 1 minute again.

5. *Artificial respiration* · Demonstrate and have the children learn the newer methods of producing artificial respiration, such as the back pressure-arm lift method and the mouth-to-mouth method. Have the children read about and report on the function and use of the iron lung for persons who are unable to use their lungs normally.

THE EXCRETORY SYSTEM

1. *The excretion of water* · Have the children recall the large drops of perspiration, containing water, that formed on their faces and bodies on a warm day after they had been running or playing actively. Let them recall how they could "see their breath" on a frosty day as the water vapor, present in the air expelled from their lungs, condensed into tiny droplets of water in the cold air. Have them breathe on a cold mirror and see the cloud or mist that forms as the water vapor from their breath condenses on the cool glass.

2. *The excretion of carbon dioxide* · Obtain some limewater from the drugstore and pour a little into a test tube. Have one of the children bubble the limewater with a soda straw until the limewater becomes milky, showing the presence of carbon dioxide. The carbon dioxide came from the air inside the child's lungs.

3. *The excretion of mineral salts* · Have the children lick their wrists after they have returned from a recess period where they had been playing actively. Point out that the salty taste is caused by the presence of mineral salts, which were dissolved in the perspiration and left behind after the perspiration evaporated.

4. *Examine an animal kidney* · Obtain the kidney of a calf, sheep, or pig from the meat market. Note the size and shape of the kidney. Observe where a large artery and a large vein enter the kidney. Cut the kidney lengthwise in half with a sharp knife. Note the many tubes in the tissue near the surface of the kidney and the large chamber where the urine collects. Point out that the urine leaves this chamber and travels through a duct that empties into the bladder.

THE NERVOUS SYSTEM

1. *The parts of the nervous system* · Obtain a chart showing the human nervous system. Locate the central nervous system, which consists of the brain and spinal cord. Observe the major nerves that spread out from the brain and spinal cord to every part of the body.

2. *Examine an animal's brain* · Obtain a fresh, undamaged brain of a calf, sheep, or pig from the meat market. Locate and identify the cerebrum, cerebellum, and medulla. Note how large the cerebrum is and how its surface is folded in many places. Cut into the gray matter of the cerebrum and note the white matter underneath. See how the cerebellum is attached to the rest of the brain. Observe how the medulla connects with the other parts of the brain and with the spinal cord.

3. *The nerve cells* · Draw a diagram of a nerve cell and label each part. Have the children stretch out their arms with the fingers spread out wide. Their hands can represent the cell bodies, their fingers the dendrites, and their arms the axons. Discuss the difference between sensory, motor, and associative nerve cells. Have the children distinguish between sensory, motor, and mixed nerves.

4. *Simple reflex action* · Have a child sit on a chair with his legs crossed so that one leg swings freely. Strike the leg just below the knee with the side of your hand. The leg will kick out immediately in a simple reflex action. Other simple reflex actions include blinking the eyes when an object suddenly comes near them, laughing when tickled, turning pale when frightened, blushing when embarrassed, coughing, yawning, sneezing, and shivering.

5. *Conditioned reflex* · Have the children recall how their mouths "water" as saliva flows when tasty food is either mentioned or seen. Develop a conditioned reflex in the children by asking them to tap their pencils every time you say the word "tap." At first strike a ruler against your desk whenever you say "tap." After you have done this for some time, strike the ruler but do not say anything. Many children will still continue to tap their pencils even though you have not said the word "tap."

THE SENSE ORGANS

1. *The sense of touch* · Touch the point of a thin, sharp nail to different spots on the back of one of the children's fingers. In some spots the child will feel only a sense of pressure. Other spots, which are more sensitive, will also produce a feeling of pain.

Spread the arms of a hairpin until the points are about 2 inches apart. Blindfold a child and touch the palm of his hand with both ends of the hairpin. The child will feel both points. Repeat the procedure, bringing the points a little closer each time. Eventually the child will say that he feels just one point. At this stage both points of the hairpin are touching just one nerve cell. Repeat the experiment on the back of the hand, the forearm, and the back of the neck. Note the differences in

frequency of distribution of the nerve cells in different parts of the body.

2. *The sense of smell* · Have the pupils sit quietly in various parts of the classroom. Pour some inexpensive strong perfume on a handkerchief and wave the handkerchief in the air. Ask the children to raise their hands as soon as they smell the perfume. Call their attention to the way that the odor diffuses progressively to all parts of the classroom.

3. *The sense of taste* · Blindfold a child and have him stick out his tongue. Wrap a bit of absorbent cotton around one end of a toothpick and dip it into a solution of sugar and water. Touch the cotton to the tip, sides, and back of the tongue and have the child identify the taste as sweet, sour, salty, or bitter in each case. Repeat the test, using a salt solution, lemon juice, and a bitter solution of an aspirin tablet in a small amount of water. The child will detect sweet flavors mostly at the tip of his tongue, salt flavors at the tip and front sides of the tongue, sour flavors along the sides of the tongue, and bitter flavors at the back of the tongue.

Point out that smell has a lot to do with taste. Blindfold a child and have him hold his nose tightly. Give him a piece of apple, pear, and potato to eat and have him try to identify what he is eating. Now let him eat a piece of apple while you hold a piece of pear under his nose. He will believe he is eating a pear. Reverse the procedure and he will now think he is eating an apple.

4. *The eye* · Obtain a chart or model of the human eye. Have the children locate and discuss the function of the main parts, including the cornea, pupil, iris, lens, vitreous and aqueous humors, retina, and optic nerve.

5. *Examine an animal's eye* · Obtain the eye of a cow, sheep, or pig from the meat market. Use a single edge razor to slice the eye in half lengthwise. The aqueous and vitreous humors will flow out. Examine the rest of the eye closely and identify each of the parts. If you can obtain another eye, dissect it carefully and remove the lens. Note that the lens is convex.

6. *A convex lens produces an image* · Tape or tack a sheet of white paper on the wall opposite a window. Draw the shades on all the windows in the room except for the window facing the paper. Hold a magnifying glass close to the paper, and move the glass back and forth until you see a clear image on the paper (Figure 15–5). The convex lens of the magnifying glass will form a smaller inverted image of the window, of whatever is on the window sill, and of objects that are outside the window at the time.

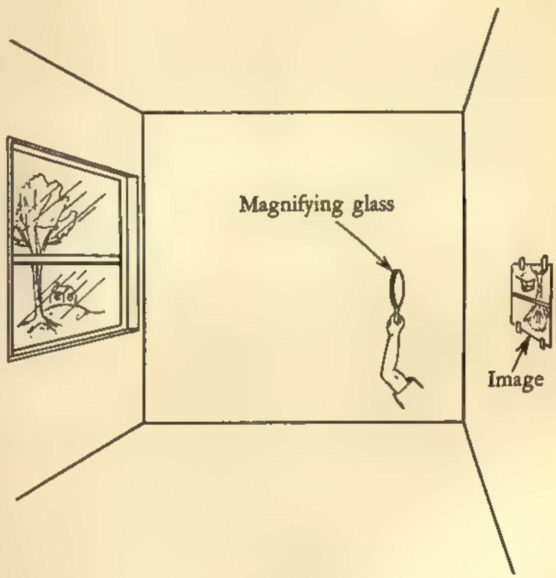


FIGURE 15–5.
A CONVEX LENS WILL PRODUCE A SMALL INVERTED IMAGE.

7. *The effect of light on the size of the pupil* · Have a child sit in the darkest part of the room for about 5 minutes. Let the other children note how large the pupil of the eye has become to admit as much light as possible into the eye. Now shine a flashlight into the

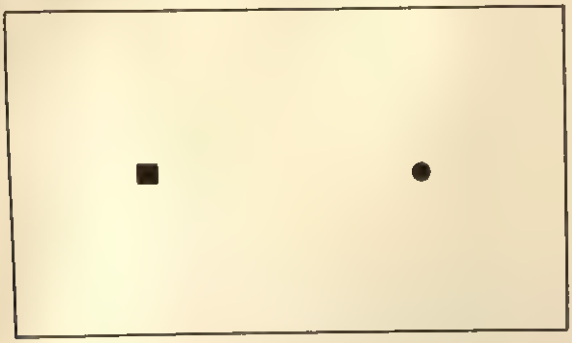


FIGURE 15–6.
FIND THE BLIND SPOT IN YOUR EYE.

child's eye. Note how quickly the pupil becomes smaller to cut down the amount of light entering the eye.

8. *The eye has a blind spot* · Make a square and a circle about 4 inches apart on a piece of white cardboard (Figure 15–6). Hold the card at arm's length. Close your left eye and look at the square with your right eye. Slowly bring the cardboard toward you, staring at the square, and yet looking at the circle from the corner of your eye. At a certain position the circle will disappear. Point out that the image of the circle has fallen on that spot of the retina where all the nerves come together and go to the brain through the optic nerve. No image can form at this spot, making it a blind spot for the eye. When you continue to bring the card closer, the circle reappears.

9. *Each eye produces a separate image* · Bring the forefinger of each hand together about 8 inches in front of you and at eye level (Figure 15–7). First look at both fingertips,

FIGURE 15–7.
IMAGES FROM EACH EYE OVERLAP TO PRODUCE A TINY THIRD FINGER.

and then look just over the fingertips at the wall across the room. You will see a third tiny finger, having two fingernails, appear between your two fingers. Point out that each eye sees both fingers, but the images from each eye overlap to produce the third finger.

10. *The retina holds an image for a short time* · Obtain a piece of sturdy white cardboard about 3 inches long and 2 inches wide. Use a black wax marking pencil to draw a fish bowl on one side and a goldfish on the other side (Figure 15–8). Make four small holes at

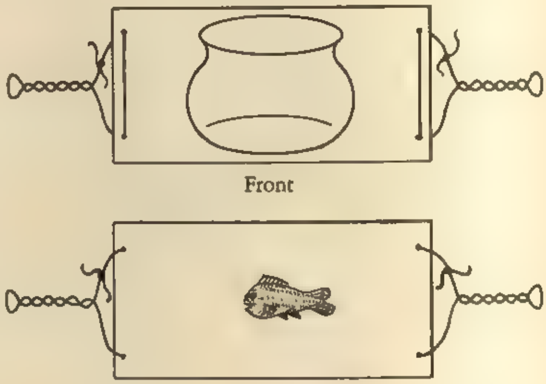


FIGURE 15–8.
PERSISTENCE OF VISION PUTS THE GOLDFISH INSIDE THE BOWL.

the corners of the cardboard and thread a 12-inch piece of fine, strong string through two of the holes on each side of the cardboard, as shown in the diagram. Twist each string as much as you can, and then insert a finger in each of the loops and twirl the card rapidly by pulling the two loops hard sideways. When the card twirls, the goldfish will seem to be inside the bowl. Point out that the eye holds an image for a short time after the object has disappeared. When the card twirls, the pictures follow each other so rapidly that you see one picture before the image of the other picture has had time to disappear. As a result, you see both pictures at the same time.

11. *Defects of the eye* · Draw diagrams on the chalkboard showing that the lens of the eye is unable to focus light on the retina in nearsightedness and farsightedness. Show how nearsightedness can be corrected with a concave lens and farsightedness with a convex lens.

Have the children test themselves for color blindness. Obtain a variety of colored threads and mix them together. Let the children take turns selecting specific colors and naming them.

12. *The ear* · Obtain a chart or model of the human ear. Have the children locate and discuss the function of the main parts of the outer, middle, and inner ear.

13. *Locating sounds* · Blindfold a child and have him sit on a chair in the center of the room. Stand at different locations in the room and strike two pencils together. The child will be able to tell from what direction the sound is coming because the sound usually reaches one ear sooner than the other. Now have the child place one finger in his ear. Repeat the procedure. This time the child will have difficulty telling from what direction the sound is coming.

14. *Sense of balance* · Have a child stand in the center of the room and spin around for a short while. When the child stops, he will still have a spinning sensation because the liquid in the semicircular canals of the inner ear is still whirling around.

THE ENDOCRINE SYSTEM

1. *The endocrine glands* · Obtain a chart or draw a diagram showing the endocrine system of the human body. Locate the pituitary gland, thyroid gland, and parathyroid glands in the head and neck region. Locate the pancreas and adrenal glands in the abdominal region. Discuss the function of each gland. Name the hormones secreted by these glands and describe the effect of these hormones on organs in other parts of the body.

2. *Diseases of the endocrine glands* · Have the children read about and report on the effects on the human body when the pituitary, thyroid, and parathyroid glands are either overactive or underactive. Let them also report on the cause of diabetes, its symptoms, and the current method of treating it.

BIBLIOGRAPHY FOR "THE HUMAN BODY"

ASIMOV, ISAAC. *The Chemical of Life.* New York: Abelard, 1954. 159 pp.

CHARLES, BENJAMIN, and SIDONIE GRUENBERG. *The Wonderful Story of You; Your Body, Your Mind, Your Feelings.* New York: Doubleday, 1960. 182 pp.

FOLLETT, ROBERT R. J. *Your Wonderful Body.* Chicago: Follett, 1961. 32 pp.

FOX, RUTH. *Milestones of Medicine.* New York: Random, 1950. 237 pp.

GALAMBOS, ROBERT. *Nerves and Muscles: An Introduction to Biophysics.* New York: Doubleday, 1962. 158 pp.

GLEMSER, BERNARD. *All About the Human Body.* New York: Random, 1958. 136 pp.

GRAMET, CHARLES. *The Wonder That Is You.* New York: Abelard, 1962. 61 pp.

GRANT, MADELEINE P. *Biology and World Health.* New York: Abelard, 1955. 202 pp.

HINSHAW, ALICE. *The True Book of Your Body and You.* Chicago: Childrens, 1959. 47 pp.

LAUBER, PATRICIA. *Your Body and How It Works.* New York: Random, 1962. 77 pp.

LEVINE, MILTON I., and JEAN H. SELIGMANN. *The Wonder of Life.* New York: Simon & Schuster, 1952. 116 pp.

LIBERTY, GENE. *The First Book of the Human Senses.* New York: Watts, 1960. 68 pp.

PARKER, BERTHA M. *Community Health.* New York: Harper, 1949. 36 pp.

———. *Foods.* New York: Harper, 1958. 36 pp.

———. *You as a Machine.* New York: Harper, 1958. 36 pp.

PARKER, BERTHA M., and M. ELIZABETH DOWNING. *How We Are Built.* New York: Harper, 1959. 36 pp.

———. *Keeping Well.* New York: Harper, 1953. 36 pp.

PERRY, JOHN. *Our Wonderful Eyes.* New York: McGraw, 1955. 158 pp.

RAVIELLI, ANTHONY. *Wonders of the Human Body.* New York: Viking, 1954. 125 pp.

REINFELD, FRED. *Miracle Drugs and the New Age of Medicine.* New York: Sterling, 1959. 116 pp.

RIEDMAN, SARAH R. *The World Through Your Senses.* New York: Abelard, 1962. 189 pp.

RUCHLIS, HYMAN. *What Makes Me Tick?* Irvington-on-Hudson, N.Y.: Harvey, 1957. 44 pp.

SCHEIB, IDA. *The First Book of Food.* New York: Watts, 1956. 65 pp.

SCHNEIDER, HERMAN, and NINA SCHNEIDER. *How Your Body Works.* Chicago: Scott, 1954. 160 pp.

SCHNEIDER, LEO. *Lifeline: The Story of Your Circulatory System.* New York: Harcourt, 1958. 127 pp.

———. *You and Your Senses.* New York: Harcourt, 1956. 137 pp.

DE SCHWEINITZ, KARL. *Growing Up.* New York: Macmillan, 1953. 73 pp.

SPROUL, EDITH E. *The Science Book of the Human Body.* New York: Watts, 1955. 232 pp.

SUTHERLAND, LOUIS. *Magic Bullets.* Boston: Little, 1956. 148 pp.

SUTTON-VANE, S. *The Story of Eyes.* New York: Viking, 1958. 221 pp.

WEART, EDITH LUCIE. *The Story of Your Blood.* New York: Coward, 1960. 64 pp.

———. *The Story of Your Brain and Nerves.* New York: Coward, 1961. 62 pp.

ZIM, HERBERT S. *Our Senses and How They Work.* New York: Morrow, 1956. 64 pp.

———. *What's Inside of Me?* New York: Morrow, 1952. 32 pp.

———. *Your Food and You.* New York: Morrow, 1957. 64 pp.

———. *Your Heart and How It Works.* New York: Morrow, 1959. 63 pp.

MATTER AND ENERGY

CHAPTER

16 Changes *in* Matter *and* Energy

THE STRUCTURE OF MATTER

I. MATTER

A. Matter is anything that takes up, or occupies, space and has weight.
   1. Air, water, wood, stones, and metals are examples of matter.
   2. Man, plants, animals, the sun, stars, and the planets are also examples of matter.

B. Some materials are made up of only one particular kind of matter, and other materials are made up of more than one kind of matter.
   1. A material that is made up of only one particular kind of matter is called a **substance.**
   2. Water, salt, sugar, silver, and oxygen are examples of substances.
   3. Air is an example of matter that is made up of many substances, such as oxygen, nitrogen, carbon dioxide, and others.

C. Matter is found in three forms, or states, and these states are called **solid, liquid,** and **gas.**

D. A solid has a definite size and shape.
   1. Wood, iron, glass, ice, rubber, wool, and butter are examples of solids.
   2. Solids can be hard or soft.

E. A liquid has a definite size, but it does not have a definite shape.
   1. Water, milk, alcohol, oil, and gasoline are examples of liquids.
   2. A liquid's shape depends upon the shape of the container into which it is poured.

F. A gas does not have either a definite size or a definite shape.
   1. Air, oxygen, carbon dioxide, and ammonia are examples of gases.
   2. When a gas is poured into a container, it spreads out until it has the same size of the container, and also takes the shape of the container.

G. Matter can be changed from one state to another by heating or cooling.
   1. When liquid water is cooled, it becomes solid ice.
   2. When liquid water is heated, it becomes a gas called **water vapor.**

H. The science that deals with the different kinds of matter around us, of what they are made, and the changes that happen to them, is called chemistry.

II. GRAVITY, WEIGHT, AND MASS

A. Every body in the universe attracts, or pulls, on every other body.

B. This attraction or pull that each body has for another is called **gravity.**

1. The larger and heavier a body, the greater its pull of gravity will be.
2. The farther away two bodies are from each other, the smaller their pull of gravity on each other will be.

C. The earth's gravity pulls on every body at or near the earth's surface.
1. This pull is always directed down toward the center, no matter where on the earth the body is located.
2. This is the reason why we say that the earth's gravity has a downward pull.
3. This downward pull of the earth's gravity keeps people from falling off the earth, and also holds the air and water on the earth.

D. The measure of the earth's pull of gravity on a body is called the **weight** of that body.
1. The weight of a body will change, depending upon its distance from the center of the earth.
2. The nearer a body is to the center of the earth, the greater the downward pull of the earth's gravity on the body will be, and the more the body will weigh.
3. The farther away a body is from the center of the earth, the smaller the downward pull of the earth's gravity on the body will be, and the less the body will weigh.

E. Each body has a **center of gravity**, which is the point where all of the weight of the body seems to be located.

F. The actual amount of matter in a body is called the **mass** of the body.
1. Man has nothing to do with the earth's pull of gravity.
2. A body will have the same amount of mass, whether it is on the earth's surface or far out into space.

III. Physical and Chemical Properties of Matter

A. All matter has certain qualities or characteristics, called **properties,** which help us tell one material from another, and also help us find out for what purposes the materials can be used.

B. These properties are divided into two main groups: **physical properties** and **chemical properties.**

C. The physical properties of a material are those qualities or characteristics that we can readily observe with our five senses and that do not cause the material to be changed into a different material.
1. Physical properties include such characteristics as color, odor, taste, heaviness, hardness, elasticity, melting and boiling temperatures, ability to dissolve in water and other liquids, and ability to conduct heat and electricity.
2. Not all materials have every one of these physical properties.

D. The chemical properties of a material are those qualities or characteristics that have to do with the activity of a material with other materials.
1. We observe chemical properties when we see air and moisture act on iron to make iron rust, vinegar act on baking soda to produce bubbles of carbon dioxide gas, and a fuel use the oxygen of air to burn.
2. In each case a new material is formed.
3. A material that acts readily with other materials is called **active,** and a material that does not act readily with other materials is called **inert.**

IV. Physical and Chemical Changes

A. There are two kinds of changes that can happen to matter: **physical changes** and **chemical changes.**
1. These changes in matter go on around us all the time.
2. These two changes are very much different from one another.

B. In a physical change, only the physical properties or characteristics of the material are changed, and it is still the same material.
1. A physical change takes place when a

material changes in size or shape, such as when wood is chopped, paper is torn, or glass is broken.

2. A physical change takes place when a material is heated and expands, or is cooled and contracts.
3. A physical change takes place when a material changes its form, or state, such as when a solid is changed into a liquid, or a liquid is changed into a gas.
4. In most physical changes, the material can be changed back into its original size, shape, or appearance.

C. In a chemical change, the chemical properties or characteristics of the material are changed so that a new material is formed, with properties that are different from the original material.

1. Examples of chemical change include the burning of wood, rusting of iron, tarnishing of silver, souring of milk, and digestion of food.
2. For a chemical change to take place, energy—such as heat, light, or electricity—is either needed or given off.

V. MOLECULES

A. All materials are made up of tiny particles called **molecules.**

1. These molecules are so small that they cannot be seen even under a microscope.
2. One drop of water is made up of billions of molecules.

B. A molecule is the smallest particle of a substance that will still be that substance, and will still have all the properties of that substance.

1. A lump of sugar can be crushed and broken up into many particles of sugar.
2. These particles of sugar can be ground into a very fine powder, but each tiny particle of powder will still be a particle of sugar.
3. If we could keep breaking up a particle of sugar over and over again into smaller and smaller particles, we would finally end up with the smallest possible particle of sugar.
4. This smallest possible particle of sugar would be one molecule of sugar.

C. All the molecules of a substance are alike, but the molecules of one substance are different from the molecules of another substance.

1. For example, all the molecules of water in a glass tumbler are alike.
2. But molecules of salt are different from molecules of sugar.

D. Molecules are always moving rapidly, striking other molecules and then bouncing off in different directions.

1. In a gas, the molecules move very fast and are far apart.
2. In a liquid, the molecules move more slowly and are closer together.
3. In a solid, the molecules are very close together, and each molecule seems to be moving back and forth, or vibrating, in one fixed position rather than moving about freely.

E. All molecules attract each other.

1. The attraction that molecules of the same substance have for each other is called **cohesion.**
2. The attraction that molecules of different substances have for each other is called **adhesion.**

F. Cohesion makes it possible for molecules to come together and form substances or materials.

1. In a solid, the attraction between molecules is very strong, so the solid holds its shape.
2. In a liquid, the attraction between molecules is much weaker, and, although the molecules still stick together, the liquid does not hold its shape but takes the shape of the container.
3. In a gas, there is practically no attraction between molecules, so the molecules move away from each other, and in this way the gas spreads throughout its container.

G. Adhesion makes it possible for two different substances to stick together.
   1. Because of the attraction of molecules of different substances for each other, paint sticks to wood.
   2. Because of adhesion, water sticks to other materials, making them wet.
   3. The action of glue, cement, and paste also depends upon adhesion.

VI. Atoms

A. Molecules are made up of even smaller particles called **atoms.**
B. In some cases a molecule is made up of just one atom.
   1. This is why the word *molecule* is often confused with the word *atom.*
   2. A molecule of iron is made up of just one atom of iron.
C. However, in most cases a molecule is made up of more than one atom.
   1. A molecule of oxygen is made up of two atoms of oxygen that are close together.
   2. A molecule of water is made up of two atoms of hydrogen and one atom of oxygen.
   3. A molecule of vinegar is made up of two atoms of carbon, four atoms of hydrogen, and two atoms of oxygen.
D. Scientists have discovered that all atoms are made up of three smaller kinds of particles: **electrons, protons,** and **neutrons.**
E. The electron is a particle with a negative (−) electrical charge.
   1. Although it has a very small mass (the amount of matter in a body), it has a great deal of energy and moves around very quickly.
   2. Because all electrons have the same negative charge, they repel each other.
   3. Electrons are so small that billions of them would be needed just to cover the head of a pin.
F. The proton is a particle with a positive (+) electrical charge.
   1. It is much heavier than the electron, having a mass about 1836 times as great as that of an electron.
   2. A proton has about the same amount of energy as an electron, but, because it is heavier, it moves more slowly than the electron.
   3. The positive (+) electrical charge of the proton is equal to the negative (−) electrical charge of the electron, but both charges are exactly opposite to each other.
   4. Because the electrical charges of the proton and the electron are unlike, or opposite, these two particles attract each other.
   5. When an electron and a proton are brought together, their electrical charges neutralize each other, which means that together the electron and proton are neither negatively nor positively charged.
G. The neutron is a particle that has a neutral charge.
   1. The neutron has neither a positive nor a negative electrical charge.
   2. As a result, the neutron does not attract or repel other neutrons.
   3. The mass of a neutron is about equal to the combined masses of one electron and one proton.
   4. It would appear, then that a neutron is made up of one electron and one proton combined together.
   5. Also, the electrical charges of the electron and proton would neutralize each other to produce a neutral charge, just like the neutral charge of the neutron.
   6. However, scientists have found that the energy of a neutron is just a little greater than the combined energies of one electron and one proton.
   7. Scientists think that a neutron is made up of an electron and a proton held together by a small particle of energy, called a **neutrino,** which has no weight or electrical charge.
H. In an atom, the heavier protons and neutrons are closely packed together and are

located in the center of the atom, which is called the **nucleus** of the atom.

1. Because protons all have the same positive (+) charge, and because the same kinds of charges always repel each other, the protons in the nucleus should also repel each other rather than stay close together.
2. Scientists believe that there is a powerful form of energy that holds or binds the protons and neutrons closely together in the nucleus of an atom.
3. This energy is called the **binding energy** of the nucleus.

I. The lighter electrons are spaced around the nucleus in rather definite regions or areas, called **shells** or **energy levels.**

1. At first scientists thought that the electrons revolved around the nucleus in paths or orbits very much like the planets revolve around the sun.
2. Now scientists believe that the electrons move about the nucleus more like bees swarming about their hive.
3. Sometimes the electrons are near the nucleus and sometimes they are farther away, depending upon how much energy they have at the moment.

J. Because every atom is made up of electrons, protons, and neutrons, scientists believe that matter is really electrical in nature.

K. Every atom is electrically neutral because it has the same number of electrons and protons in it.

L. The difference between the atoms of different substances lies only in the number of electrons, protons, and neutrons the atoms of these substances have.

M. Although an atom may have many electrons, protons, and neutrons, the atom is mostly empty space.

1. The nucleus is small compared to the rest of the atom, and all the protons and neutrons in the nucleus are packed very tightly together.
2. But the electrons, in their different shells or energy levels, are spread out so that there is a vast amount of space between the nucleus and the electrons.
3. If an atom could be magnified so that it was as large as a football field, the nucleus would be no larger than a tiny grain of sand in the middle of the field.

VII. Elements

A. Although all atoms are made up of electrons, protons, and neutrons, all atoms do not have the same number of these particles in them.

B. Atoms differ in the number of electrons, protons, and neutrons they have, and, because of this difference, there are different kinds of atoms.

C. There are 92 different kinds of atoms found on earth.

1. Each different kind of atom is called an **element.**
2. Each element has its own particular number of protons and neutrons in the nucleus and electrons outside the nucleus.
3. The atoms of each element are exactly the same, but the atoms of one element are different from the atoms of another element.

D. Chemists also define an element as a simple substance that cannot be broken up into anything simpler by ordinary means.

E. Elements are often called the building blocks of matter.

1. Elements can combine with each other to form new substances.
2. All the materials on earth are made up of different combinations of these 92 natural elements.

F. In addition to the 92 natural elements, man has made 11 elements himself, bringing the total number to 103 elements.

G. Chemists divide the elements into two main groups because the elements in each group have many properties in common.

H. The elements in one group are called **metals.**

1. Most metals have a special shiny surface, called a metallic luster.

2. Most metals conduct electricity and heat very well.
3. Many metals are **ductile,** which means they can be drawn out into wire.
4. Many metals are also **malleable,** which means they can be hammered into thin sheets.
5. Examples of metals are gold, silver, copper, iron, and aluminum.

I. The elements in the second group are called **nonmetals.**
1. Almost all the nonmetals are either gases or brittle solids.
2. Most nonmetals conduct electricity and heat very poorly.
3. Solid nonmetals cannot be drawn into wire or hammered into sheets because they are so brittle.
4. Examples of nonmetals are sulfur, carbon, oxygen, hydrogen, and nitrogen.

VIII. Symbols

A. Chemists use a **symbol** for the name of an element instead of writing out the whole word.

B. Sometimes the symbol is just one letter of the alphabet.
1. In this case we use the first letter of the name of the element as the symbol.
2. Examples of symbols with one letter are C for carbon, H for hydrogen, and O for oxygen.

C. Sometimes the symbol is two letters of the alphabet.
1. Two letters are used when we have two or more elements whose names begin with the same first letter.
2. In this case the symbol is made up of the first letter of the name of the element together with another letter that helps identify the element.
3. Examples of symbols with two letters are Ca for calcium, Co for cobalt, and Cr for chromium.

D. The first letter of a symbol is always a capital letter, but the second letter is always a small letter.

E. For many of the elements the symbol is taken from the Latin name for the element.
1. Most of these elements were well known long before English was spoken, and had been called by their Latin names for a long time.
2. Iron has the symbol Fe, which comes from the Latin word *ferrum.*
3. Lead has the symbol Pb, which comes from the Latin word *plumbum.*
4. Silver has the symbol Ag, which comes from the Latin word *argentum.*
5. Copper has the symbol Cu, which comes from the Latin word *cuprum.*

F. Some common elements and their symbols are shown in Table 16–1.

TABLE 16–1. Some Common Elements and Their Symbols

ELEMENT	SYMBOL	ELEMENT	SYMBOL
Aluminum	Al	Neon	Ne
Arsenic	As	Nickel	Ni
Calcium	Ca	Nitrogen	N
Carbon	C	Oxygen	O
Chlorine	Cl	Phosphorus	P
Copper	Cu	Platinum	Pt
Fluorine	F	Silicon	Si
Gold	Au	Silver	Ag
Helium	He	Sodium	Na
Hydrogen	H	Sulfur	S
Iodine	I	Tin	Sn
Iron	FE	Tungsten	Wo
Lead	Pb	Radium	Ra
Magnesium	Mg	Uranium	U
Mercury	Hg	Zinc	Zn

IX. The Atomic Structure of the Elements

A. The difference between the atoms of the different elements is in the number of electrons, protons, and neutrons that the atoms of these elements have.

B. At the same time there is also a definite arrangement of all the electrons, protons, and neutrons in the atoms of every single element.

C. In all atoms the protons and neutrons are located in the nucleus, and the electrons

are located in shells or energy levels outside the nucleus.

D. The number of protons in the nucleus of an atom is called the **atomic number** of the atom.
  1. This number of protons in the nucleus varies for the atoms of each element.
  2. For example, an atom of the element oxygen has 8 protons in its nucleus and its atomic number is 8; and an atom of iron has 26 protons in its nucleus and its atomic number is 26.

E. The atomic number of an element definitely identifies the element, and determines the chemical properties of that element as well.
  1. For example, the element hydrogen is made up of atoms, all having one proton in their nucleus, so the atomic number is 1.
  2. Therefore, any atom that has a nucleus with just one proton in it must have an atomic number of 1, and will be a hydrogen atom with all the chemical properties of the element hydrogen.

F. It is possible to arrange all 103 elements in a table of atomic numbers that range from 1 to 103.
  1. In this table the first element has an atomic number of 1, the next element has an atomic number of 2, the third element an atomic number of 3, and so on until the last element, which has an atomic number of 103.
  2. Each element in the table has an atomic number that is one number higher (one more proton) than the element above it, and one number lower (one less proton) than the element below it.

G. Because atoms are electrically neutral, there must be the same number of negatively charged (−) electrons outside the nucleus as there are positively charged (+) protons inside the nucleus.
  1. Because there is this equal number of positive and negative charges, they balance each other and make the atom electrically neutral.
  2. An atom of hydrogen, with an atomic number of 1, has one proton in its nucleus and one electron outside the nucleus.
  3. An atom of uranium, with an atomic number of 92, has 92 protons in its nucleus and 92 electrons outside the nucleus.

H. The electrons are spaced around the nucleus in shells or energy levels.
  1. Chemists have found that there are seven shells or energy levels that the electrons can occupy.
  2. There is a definite limit to the number of electrons that there can be in each shell.
  3. For example, there can be no more than 2 electrons in the first shell or energy level nearest the nucleus, 8 electrons in the second shell or energy level, 18 electrons in the third shell or energy level, and 32 electrons in the fourth shell or energy level.
  4. Generally, the farther away the shells or energy levels are from the nucleus, the more energy the electrons in these shells or energy levels will have.
  5. When chemical changes take place, it is because of the action between the high-energy electrons in the outermost shells or energy levels of the atoms of two or more different elements.

I. The weight of an atom is called its **atomic weight.**
  1. The atomic weight of an atom is the weight of all the electrons, protons, and neutrons in the atom.
  2. Because the electrons have so little weight, for all practical purposes the weight of the atom can be said to be the weight of the protons and neutrons in the nucleus.
  3. Also, because a proton and a neutron have just about the same weight, the number of neutrons in a nucleus can be found by subtracting the atomic number from the atomic weight.
  4. For example, if the atomic number of

the element aluminum is 13 and its atomic weight is 27, this means that there are 13 protons and 27 minus 13, or 14, neutrons in the nucleus.

5. In general, as the atomic numbers of the different atoms increase, the atomic weights increase as well.

J. The atomic structure of the simplest element, hydrogen, is as follows.
   1. The hydrogen atom has an atomic number of 1 and an atomic weight of 1.
   2. The atomic number of 1 means that there is one proton in the nucleus and one electron in the first shell or energy level outside the nucleus.
   3. The one proton in the nucleus makes up the atomic weight of 1.

K. The atomic structure of the next simplest element, helium, is as follows.
   1. The helium atom has an atomic number of 2 and an atomic weight of 4.
   2. The atomic number of 2 means that there are two protons in the nucleus and two electrons in the first shell or energy level outside the nucleus.
   3. There are 4 minus 2, or two, neutrons in the nucleus, which together with the two protons make up the atomic weight of 4.

L. The atomic structure of the next element, lithium, is as follows.
   1. The lithium atom has an atomic number of 3 and an atomic weight of 7.
   2. This means that there are three protons in the nucleus and three electrons outside the nucleus.
   3. Two of the three electrons are in the first shell or energy level outside the nucleus, and the other electron is in the second shell or energy level.
   4. There are 7 minus 3, or four, neutrons in the nucleus, which together with the three protons make up the atomic weight of 7.

M. The atomic structure for the first 24 elements is given in Table 16–2.

TABLE 16–2. Atomic Structure of the First 24 Elements

ELEMENT	ATOMIC NUMBER	ATOMIC WEIGHT	NUMBER OF PROTONS	NUMBER OF NEUTRONS	ARRANGEMENT OF ELECTRONS BY ENERGY LEVELS
Hydrogen	1	1	1	0	1
Helium	2	4	2	2	2
Lithium	3	7	3	4	2,1
Beryllium	4	9	4	5	2,2
Boron	5	11	5	6	2,3
Carbon	6	12	6	6	2,4
Nitrogen	7	14	7	7	2,5
Oxygen	8	16	8	8	2,6
Fluorine	9	19	9	10	2,7
Neon	10	20	10	10	2,8
Sodium	11	23	11	12	2,8,1
Magnesium	12	24	12	12	2,8,2
Aluminum	13	27	13	14	2,8,3
Silicon	14	28	14	14	2,8,4
Phosphorus	15	31	15	16	2,8,5
Sulfur	16	32	16	16	2,8,6
Chlorine	17	35	17	18	2,8,7
Argon	18	40	18	22	2,8,8
Potassium	19	39	19	20	2,8,8,1
Calcium	20	40	20	20	2,8,8,2
Scandium	21	45	21	24	2,8,9,2
Titanium	22	48	22	26	2,8,10,2
Vanadium	23	51	23	28	2,8,11,2
Chromium	24	52	24	28	2,8,13,1

N. Not all the atoms of the same element have the same weight.
   1. Some atoms of an element have a slightly different number of neutrons from other atoms of the same element.
   2. Because of this difference in the number of neutrons, some atoms of an element have a different atomic weight from other atoms of the same element.
   3. However, even though these atoms of the same element differ in atomic weight, they all still have the same atomic number so they are all part of the same element and have the same chemical properties of that element.
   4. Atoms of an element that have the same atomic number but a different atomic weight are called **isotopes** of that element.
   5. Isotopes of the same element have the same number of protons and electrons but have a slightly different number of neutrons.
   6. Isotopes can occur naturally or they can be produced artificially by man.

O. The element hydrogen has three known isotopes.
   1. Hydrogen has an atomic number of 1, which means that all three isotopes have one proton in the nucleus and one electron outside the nucleus.
   2. The most common isotope has just the one proton in the nucleus, so its atomic weight is 1.
   3. A second isotope, called **deuterium,** has a neutron in the nucleus, as well as the one proton, so its atomic weight is 2.
   4. The third isotope, called **tritium,** has two neutrons in the nucleus, as well as the one proton, so its atomic weight is 3.
   5. Because all three isotopes have different weights, the average atomic weight of hydrogen is 1.0078.

P. A radioactive isotope of the element carbon is being used to estimate the age of rocks and minerals.
   1. Carbon has an atomic number of 6, which means that all isotopes of carbon have six protons in the nucleus and six electrons outside the nucleus.
   2. The common isotope of carbon has an atomic weight of 12, so there are 12 minus 6, or six, neutrons in the carbon-12 atom.
   3. The radioactive isotope of carbon has an atomic weight of 14, so there are 14 minus 6, or eight, neutrons in the carbon-14 atom.

Q. Two of the element uranium's many isotopes have atomic weights of 238 and 235.
   1. Both these isotopes have the same atomic number of 92 so there are 92 protons in the nucleus and 92 electrons outside the nucleus.
   2. In the uranium-238 isotope, there are 238 minus 92, or 146, neutrons in the nucleus.
   3. In the uranium-235 isotope there are 235 minus 92, or 143, neutrons in the nucleus.

X. Compounds and Mixtures

A. All the materials that make up matter can be divided into three main classes: **elements, compounds,** and **mixtures.**

B. Because there are only 92 natural elements on earth, most materials are either compounds or mixtures.

C. A compound is a substance that is made up of two or more elements that have combined in such a way that each element has lost its own special physical and chemical properties.
   1. As a result, the compound is a new substance with physical and chemical properties different from those of the elements that formed the compound.
   2. This means that a chemical change takes place when a compound is formed, with energy being either given off or required.

D. Every compound has its own special properties, and in this way it is possible for us to tell one compound from another.

E. A compound is always made up of the same elements, and the number of atoms

of each element that combine to form one molecule of the compound is always the same.

1. Water is a compound that is made from the elements hydrogen and oxygen, and there are always two atoms of hydrogen and one atom of oxygen in a molecule of water.
2. Sodium chloride (table salt) is a compound that is made from the elements sodium and chlorine, and there always are one atom of sodium and one atom of chlorine in a molecule of sodium chloride.
3. Ammonia gas is a compound that is made from the elements nitrogen and hydrogen, and there always are one atom of nitrogen and three atoms of hydrogen in a molecule of ammonia.

F. The elements in a compound cannot be separated very easily, and some form of energy, such as electricity or heat, is needed to make the separation take place.

G. Because there are 92 natural elements, it is possible to make a vast number of compounds by using different combinations of elements.

1. A few elements, like helium and neon, never combine to form compounds.
2. Also, some elements, like gold and platinum, do not combine very easily to form compounds.
3. There are enough elements that do combine, however, to form hundreds of thousands of compounds.

H. A mixture is a substance that is made up of two or more elements or compounds that have combined in such a way that each element or compound has not lost its own special physical and chemical properties.

1. As a result, no new substance has been formed.
2. Energy, such as heat or electricity, is not given off or required when a mixture is formed.

I. The amounts of the different materials that make up a mixture are not fixed so that any amount of one material can be mixed with any amount of other materials.

J. Air is a good example of a mixture.

1. Air is made up of many gases, including oxygen, nitrogen, carbon dioxide, and water vapor.
2. Each gas has not combined with the other, and each gas still has its own special physical and chemical properties.
3. The amounts of each gas in the air are not fixed, and they will change from time to time.

K. The materials in a mixture can be separated very simply.

1. This separation is usually made by making use of the physical properties of the materials, such as size, weight, color, and ability to dissolve in water or other liquids.
2. For example, when a strong magnet is stirred in a mixture of iron powder and sulfur powder, the magnet picks up all the iron powder, separating the iron from the sulfur.

XI. Formulas

A. Chemists use a combination of symbols and, where necessary, small numbers beside the symbols to show the makeup of a compound.

B. This combination of symbols and small numbers is called a **formula.**

C. A chemical formula tells us two things.

1. It tells us what elements are in the compound.
2. It tells us how many atoms of each element are in a molecule of the compound.

D. The formula for water is H_2O.

1. This formula shows that water is made up of the elements hydrogen and oxygen.
2. It also shows that a molecule of water contains two atoms of hydrogen and one atom of water.

E. The formula for cane sugar is $C_{12}H_{22}O_{11}$.

1. This formula shows that sugar is made

up of the elements carbon, hydrogen, and oxygen.

2. It also shows that a molecule of cane sugar contains 12 atoms of carbon, 22 atoms of hydrogen, and 11 atoms of oxygen.

F. A list of some common compounds and their formulas is shown in Table 16–3.

TABLE 16–3. Some Common Compounds and Their Formulas

COMPOUNDS	FORMULAS
Ammonia	NH_3
Baking soda (sodium bicarbonate)	$NaHCO_3$
Carbon dioxide	CO_2
Carbon monoxide	CO
Lime (calcium oxide)	CaO
Limestone (calcium carbonate)	$CaCO_3$
Salt (sodium chloride)	$NaCl$
Sand (silicon dioxide)	SiO_2
Sugar	$C_{12}H_{22}O_{11}$
Sulfuric acid	H_2SO_4
Vinegar (acetic acid)	$HC_2H_3O_2$
Water	H_2O

XII. TYPES OF CHEMICAL CHANGES OR REACTIONS

A. Chemical changes are also called **chemical reactions.**

B. All chemical changes or reactions can be grouped into the following four general kinds or types: **combination, decomposition, simple replacement,** and **double replacement** reactions.

C. In combination reactions, two or more elements or compounds combine to form a larger and more complicated compound.

1. For example, the elements carbon and oxygen combine to form carbon dioxide.
2. Also, the compounds water and carbon dioxide combine to form carbonic acid.

D. Chemists use **equations** to describe what happens during a chemical change or reaction.

1. These equations use formulas to tell us what materials took part in the chemical change or reaction, and what new materials were formed.
2. For the two combination reactions described in C above, the equations are as follows:

$$C + O_2 \longrightarrow CO_2$$

$$H_2O + CO_2 \longrightarrow H_2CO_3$$

E. In decomposition reactions, a compound is broken up into the elements that formed it, or into simpler compounds.

1. For example, iron sulfide can be broken up into iron and sulfur, as follows:

$$FeS \longrightarrow Fe + S$$

2. Also, limestone (calcium carbonate) can be broken up into lime (calcium oxide) and carbon dioxide, as follows:

$$CaCO_3 \longrightarrow CaO + CO_2$$

F. In simple replacement reactions, a free element replaces another element from a compound.

1. For example, free iron will replace copper sulfate to form free copper and the compound iron sulfate, as follows:

$$Fe + CuSO_4 \longrightarrow Cu + FeSO_4$$

2. Also, free zinc will replace hydrogen from sulfuric acid to form free hydrogen gas and the compound zinc sulfate, as follows:

$$Zn + H_2SO_4 \longrightarrow H_2 + ZnSO_4$$

G. In double replacement reactions, the element in one compound trades places with the element in another compound to form two new compounds.

1. For example, the silver in silver nitrate trades places with the sodium in sodium chloride when both chemicals are first dissolved in water and then mixed together.
2. Two new compounds, silver chloride and sodium nitrate, are formed.

3. The equation for this reaction is as follows:

$$AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$$

XIII. Solutions

A. When a lump of sugar is added to a glass of water, the sugar gradually disappears.
   1. By tasting the water, we can tell there is sugar in the water.
   2. What has happened is that the molecules of sugar have spread out and moved between the molecules of water.
   3. The water has the same amount of sweetness all over because the molecules of sugar have spread out evenly and equally between all the molecules of water.
   4. We say that the sugar **dissolves** in the water.

B. This mixture of sugar in water is called a **solution.**
   1. Chemists call a solution any mixture of two substances or materials where the molecules of one substance are spread out evenly and equally between the molecules of the other substance.
   2. The substance that dissolves is called the **solute.**
   3. The solute can be either a solid, liquid, or gas.
   4. The substance that does the dissolving is called the **solvent.**
   5. The solvent is usually a liquid, such as water, although it can also be a gas or a solid.
   6. In a sugar solution, the sugar is the solute and the water is the solvent.

C. A **dilute** solution is one where only a small amount of solute is dissolved in the solvent.

D. A **concentrated** solution is one where a large amount of solute is dissolved in the solvent.

E. A **saturated** solution is one where as much solute as possible is dissolved in the solvent at a certain temperature and pressure.

F. The most common type of solution is one where a solid dissolves in a liquid.

G. Other common types of solutions are the following.
   1. A solution of a gas in a liquid, such as carbon dioxide gas dissolved under pressure in water to form soda water.
   2. A solution of a gas in a gas, such as air for example, where the several gases in the air are spread out evenly and equally among each other.
   3. A solution of a liquid in a liquid, such as a solution of alcohol and water.

H. Chemists use special words to tell whether a substance will or will not dissolve.
   1. For example, when a solid can dissolve in a liquid, we say that the solid is **soluble** in the liquid.
   2. A solid that does not dissolve in a liquid is said to be **insoluble.**
   3. When two liquids mix to form a solution, we say that the two liquids are **miscible.**
   4. Two liquids that will not mix to form a solution are said to be **immiscible** or **nonmiscible.**

I. Usually solids dissolve better in hot liquids than in cold liquids so that more of the solid will dissolve in the liquid when it is hot than when it is cold.
   1. More sugar can dissolve in hot water than in cold water.
   2. Some solids, such as salt, are just as soluble in hot liquids as in cold liquids, which means that just as much salt will dissolve in hot water as in cold water.
   3. Some solids, such as calcium sulfate, are less soluble in hot liquids than in cold liquids, which means that less calcium sulfate will dissolve in hot water than in cold water.

J. Gases usually dissolve better in cold liquids than in hot liquids, which means that less of a gas will dissolve in a hot liquid than in a cold liquid.

1. When a glass of cold water is allowed to stand in a warm room for a while, bubbles of air collect on the sides of the glass.
2. What happens is that, as the water becomes warmer, it cannot hold as much of the air dissolved in it, so some of the air comes out of the water.

K. An increase in pressure usually makes a gas more soluble in a liquid.
1. Soda water is water in which much carbon dioxide has been made to dissolve by using great pressure.
2. When the cap is removed from a bottle of soda water, the pressure is now lessened or reduced, and carbon dioxide escapes from the solution in the form of gas bubbles.

L. There are three ways to make solids dissolve more quickly in a liquid.
1. **Stirring** will help the molecules of the solid spread quickly throughout the molecules of the liquid, and at the same time bring fresh parts of the liquid in contact with particles of the solid that have not yet dissolved.
2. **Powdering** the solid will allow more of the liquid to come in contact with the solid at one time, and this increased contact will help the solid dissolve more quickly.
3. **Heating** the liquid will make the molecules of liquid move more quickly so that the particles are spread more quickly throughout the molecules of the liquid, and at the same time fresh parts of the liquid will come more quickly in contact with particles of still undissolved solid.

XIV. The Law of Conservation of Matter

A. In many chemical changes, such as when hydrogen gas and oxygen gas combine to form water, it seems as if new matter has been created.

B. In other chemical changes, such as when a candle burns, matter seems to disappear, and we get the impression that matter has been destroyed.

C. However, the **law of conservation of matter** tells us that, in ordinary chemical reactions, matter is neither created nor destroyed, but only changed from one form to another.
1. When wood is burned in air, gases are formed and ashes are left behind.
2. We can show that the combined weight of the wood and the air that was used to burn the wood are exactly equal to the combined weight of the ashes and gases that are formed.
3. So, in this chemical change, the matter changes from one form to another, but the amount of matter itself does not change.

ENERGY

I. What Energy Is

A. Energy is the ability of matter to move other matter or to produce a chemical change in other matter.
1. Scientists also define energy as the ability to do work, usually when they are talking about machines.
2. According to scientists, work is done only when a force, which is a push or a pull, is moved through a distance.

B. There are two kinds of energy: **kinetic energy** and **potential energy.**

C. Kinetic energy is the energy that a body has because it is moving.
1. Kinetic energy, therefore, is the energy of motion, and is an active energy.
2. A moving automobile, falling water, a

strong wind, and expanding gas are all examples of kinetic energy.

D. Potential energy is the energy that a body has because of its position or condition.
   1. Potential energy is stored-up energy.
   2. It will not do any work until it is set free or released.
   3. A rock held over a cliff has potential energy because it is in a position to do work when it is released.
   4. Water at the top of a dam or waterfall also has potential energy because of its position.
   5. A stretched rubber band and a wound-up spring both have potential energy because they are in a condition to do work when they are released.
   6. A chemical, such as gunpowder, also has potential energy because it is in a condition to do work when it ignites and explodes.
   7. The chemicals in a dry cell have potential energy because they are in a condition to do work when the dry cell is connected to an appliance.

E. When potential energy is set free, it is changed to kinetic energy.
   1. When water at the top of a dam or waterfall falls down, it moves faster and faster, gaining more and more kinetic energy, and, when the water hits the bottom, all its potential energy has been changed to kinetic energy.
   2. The potential energy of a stretched rubber band and wound-up spring is changed to kinetic energy when the band and spring are released.
   3. The potential energy of gunpowder is changed to kinetic energy when the gunpowder explodes.

II. Forms of Energy

A. There are many forms of energy.

B. Scientists divide these forms into six main groups as follows: **mechanical energy, heat energy, electrical energy, wave energy, chemical energy,** and **nuclear energy.**

C. Mechanical energy is the form we see most often around us.
   1. All moving bodies produce mechanical energy.
   2. The energy produced from all kinds of machines is mechanical energy.

D. Heat energy is the energy produced by the moving molecules in a material.
   1. The faster the molecules move, the more heat energy the material has, and the hotter the material becomes.
   2. Heat energy heats our homes, dries our clothes, cooks our food, and runs power plants.

E. Electrical energy is the energy produced by electrons moving through a material.
   1. A stream of these electrons moving through a material is called an electric current.
   2. Electrical energy lights our homes, runs motors, and makes our telephones, radios, and television sets operate.

F. Wave energy is energy that travels in waves.

G. One kind of wave energy is **sound energy,** which is produced when matter moves back and forth, or vibrates, rapidly.

H. Another kind of wave energy is **radiant energy.**
   1. There are many different forms of radiant energy.
   2. These forms include light rays, X-rays, radio waves, infrared rays, ultraviolet rays, cosmic rays, and radiant heat.

I. Chemical energy is really a form of potential energy because the energy is stored in materials.
   1. This chemical energy is released when two or more materials act on each other to form new materials.
   2. The new materials are formed because of the action between high-energy electrons in the atoms of the different materials.

J. Nuclear energy is a newly discovered form of energy.
   1. It comes from the nucleus of the atom when the atom breaks up or splits in two.

2. This nuclear energy is very powerful.

III. The Transformation and Conservation of Energy

A. Energy can be changed from one form into another.

B. The production of electricity in a power plant shows very well how energy can be changed from one form to another.

1. When coal or another fuel is burned, the chemical energy in the fuel is released and changed into heat energy.
2. The heat energy is used to change water into steam.
3. The steam then turns a turbine to produce mechanical energy.
4. The turbine runs an electric generator, or dynamo, that changes mechanical energy into electrical energy.
5. The electrical energy may then be changed in a light bulb into light energy or it may be changed in the doorbell to sound energy.

C. In all these changes, the energy is not destroyed, but rather changed from one form to another.

D. The law of conservation of energy tells us that energy is neither created nor destroyed, but only changed from one form to another.

E. When energy is changed from one form to another, other forms of energy are also produced.

1. Usually these other forms of energy are not wanted, and are wasted because we have no use for them.
2. For example, when we get light energy from an electric light bulb, unwanted and unused heat energy is also produced at the same time.
3. When we get mechanical energy from a machine, unwanted and unused heat energy is also produced.
4. When we get heat energy from an electric toaster, unwanted and unused light energy is also produced.

IV. How Matter and Energy Are Related

A. For a long time scientists believed that matter and energy were completely different from one another.

1. Matter took up space and had weight but energy did not.
2. According to the law of conservation of matter, matter could be changed from one form to another, but could not be created or destroyed.
3. Also, according to the law of conservation of energy, energy could be changed from one form to another, but could not be created or destroyed.

B. In 1905, however, Einstein proposed his famous theory, which said that matter and energy are related to each other.

1. According to Einstein, matter could be changed into energy, and energy could be changed into matter.
2. Matter could be destroyed, but it would reappear as newly created energy.
3. Energy could be destroyed, but it would reappear as newly created matter.

C. Einstein's theory is usually expressed by the mathematical formula: $e = mc^2$.

1. e stands for the amount of energy.
2. m stands for the mass (the amount of matter in a body).
3. c stands for the speed of light (186,000 miles a second).
4. c^2 means that the value for the speed of light is multiplied by itself.
5. Thus, the formula reads: energy equals mass times the speed of light times the speed of light.

D. Einstein's theory could not be proved until scientists began to study the atom.

E. They discovered that, when certain atoms break up into simpler atoms, the simpler atoms all together weigh less than the original atom from which they came.

1. But, when the atoms do break up into simpler atoms, a tremendous amount of energy is also given off.
2. Evidently some of the matter in the atom turns into energy.

F. The scientists also found that, when energy is used to make an electron move faster, the mass of the electron becomes greater.
   1. Giving the electron energy not only increased its speed, but its mass as well.
   2. Evidently some of the added energy turned into matter.

G. These two findings showed that the law of conservation of matter and the law of conservation of energy do not always hold true.

H. Today scientists combine both laws into a single law, called the **law of conservation of matter and energy.**
   1. According to this law, neither matter nor energy can be destroyed, but either can be changed into other forms of matter or energy.
   2. Matter can be changed into energy, and energy can be changed into matter.
   3. As a result, the total amount of matter and energy in the universe always stays the same.

NUCLEAR ENERGY

I. Atomic Energy

A. For a long time scientists believed that the atom had a tremendous amount of energy locked up in it.

B. They were able to prove this when they learned how to split the atom.

C. They found that this energy, which was released when the atom was split, came from the nucleus.

D. At first scientists called this energy **atomic energy,** but now it is more commonly and properly called **nuclear energy.**

II. Natural Radioactivity

A. Certain elements, such as radium and uranium, have been found to give off invisible radiations, or rays.

B. These radiations have very peculiar properties.
   1. They can penetrate solid materials, such as paper, wood, thin sheets of metal, and flesh.
   2. They affect a photographic negative in exactly the same way as visible light affects the negative when it is exposed to light.
   3. They can stop seeds from germinating, kill bacteria, and destroy small animals.
   4. A person exposed to these rays for some time will receive severe burns, which take a long time to heal or may even kill the person.

C. When compounds of these elements are added to certain other compounds, the mixture will become **fluorescent,** or glow in the dark.
   1. For example, when a very small amount of radium bromide is mixed with zinc sulfide, the zinc sulfide will glow in the dark.
   2. This mixture is used to make luminous paint for coating the hands and dials of clocks, watches, and airplane instruments.

D. These elements and their compounds also give off heat and visible light, as well as invisible radiations.

E. Elements that give off these invisible radiations are said to be **radioactive,** and this highly unusual property is called **radioactivity.**

III. The Nature of Radioactivity

A. Scientists have studied these radioactive elements and their invisible radiations very carefully.

B. They discovered that these radiations are

produced because the radioactive elements are breaking up.

1. In all cases it has been found that the breakup takes place in the nucleus of the atom.
2. While the breakup is going on, three different kinds of invisible radiations are given off.
3. Two of these radiations are really particles of matter, called **alpha particles** and **beta particles.**
4. The third radiation is an energy ray, called a **gamma ray.**

C. Alpha particles are the nuclei of helium atoms.

1. Each helium nucleus has two protons and two neutrons, and is about four times as heavy as a hydrogen atom.
2. Because of the positively charged protons in the helium nucleus, an alpha particle is positively charged.
3. When an alpha particle, or helium nucleus, gains two electrons, it becomes a helium atom.
4. Alpha particles have a speed of about 10,000 to 20,000 miles a second.
5. They have the smallest penetrating power of the three invisible radiations given off by radioactive elements, and can be stopped by a thin sheet of paper or aluminum foil.

D. Beta particles are electrons traveling at high speeds.

1. These electrons are given off by the neutrons in the nucleus of the radioactive element.
2. They are negatively charged, and travel at a speed of 60,000 to 160,000 miles a second.
3. Because of their high speed, beta particles have a high penetrating power, and a good-sized sheet of aluminum metal is needed to stop them.

E. Gamma rays are high-energy X-rays.

1. They have more penetrating power than the other two radiations.
2. Very thick layers of lead or concrete are required to stop them.

F. Scientists believe that radioactive elements break up because the nuclei of their atoms are unstable.

1. These unstable nuclei give off either alpha or beta particles.
2. New nuclei are formed, which are a little lighter and are more stable than the original nuclei.
3. Scientists believe that gamma rays are produced because changes in energy levels take place in the nucleus when the new nuclei are formed.
4. At the same time, while the radioactive elements are breaking up, a small amount of their matter is changed into tremendous amounts of energy.

G. When the unstable nuclei of radioactive elements give off alpha particles, new elements are formed.

1. An alpha particle is a helium nucleus, with two protons and two neutrons in it.
2. When an atom of a radioactive element loses an alpha particle from its nucleus, this means that the nucleus has lost two protons so the atomic number (number of protons in the nucleus) is now 2 less than it was before.
3. Because the atomic number has changed, an atom of a new element has now been formed.
4. Also, because the two protons and two neutrons in the alpha particle give it an atomic weight of 4, the loss of an alpha particle from the nucleus means that the atomic weight of the new element is 4 less than the atomic weight of the original element.
5. An example of how the loss of an alpha particle produces a change in atomic number and atomic weight is shown by the radioactive element radium, which has an atomic number of 86 and an atomic weight of 222.
6. When the nucleus of a radium atom loses an alpha particle, an atom of the element radon is formed, with an atomic number of 84 and an atomic weight of 218.

H. When the unstable nuclei of radioactive elements give off beta particles, new elements are also formed.
   1. A beta particle is an electron given off by a neutron in the nucleus.
   2. When a neutron gives off an electron, the neutron becomes a proton.
   3. As a result, there is now one more proton in the nucleus than there was before so the atomic number has been increased by 1.
   4. The new atomic number means that a new element has been formed.
   5. Because an electron has little or no weight, the loss of a beta particle does not change the weight of the new element that has been formed.
   6. An example of how the loss of a beta particle produces a change in atomic number but not in atomic weight is shown by the radioactive element thorium, which has an atomic number of 90 and an atomic weight of 234.
   7. When an atom of thorium loses a beta particle, an atom of the element protoactinium is formed, with an atomic number of 91 and an atomic weight of 234.

I. The unstable nuclei of radioactive elements keep on giving off either alpha or beta particles, accompanied by gamma rays in each case, forming lighter and more stable nuclei until a nucleus is finally formed that is completely stable.
   1. When this condition results, radioactivity stops and no more alpha or beta particles and gamma rays are given off.
   2. For example, the radioactive element uranium goes through a series of breakups, giving off either alpha or beta particles and forming new radioactive elements with each breakup, until it finally becomes lead, which is nonradioactive and stable.

J. The stability of a nucleus seems to depend upon a comparison of the number of protons and neutrons in the nucleus.
   1. The most stable nuclei have the same number of protons and neutrons.
   2. The less stable nuclei have more neutrons than protons in the nucleus.
   3. The greater the difference between the number of neutrons and protons in the nucleus, the more unstable the nucleus is likely to be.
   4. Furthermore, nuclei with even numbers of both neutrons and protons are the most stable.
   5. Nuclei with an even number of neutrons and an odd number of protons (or vice-versa) are less stable.
   6. Nuclei with odd numbers of both neutrons and protons are the least stable.

IV. The Life of Radioactive Elements

A. Radioactivity is much different from ordinary chemical changes that take place around us.
   1. Ordinary changes can be speeded up or slowed down by changes in heat, pressure, or other means.
   2. However, radioactive elements break up at a steady rate of speed, which cannot be changed by any means at all.

B. The life of radioactive elements varies greatly.
   1. Some elements take billions of years to break up into simpler elements.
   2. Others take days, hours, minutes, or even seconds to break up.

C. The time required for one half of the atoms in a piece of radioactive element to break up into simpler atoms is called the half-life of that element.

D. Each radioactive element has its own half-life.

E. Radium has a half-life of 1600 years.
   1. This half-life means that half of the atoms in a piece of radium will break up into simpler atoms in 1600 years.
   2. One half of the radium atoms that remain, or one fourth of the original number, will break up in the next 1600 years.
   3. One half of the remaining radium atoms, or one eighth of the original num-

ber, will break up in the next 1600 years.

4. The radium atoms will keep on breaking up this way as long as there are radium atoms present.

F. The half-life of uranium-238 is about 5 billion years.

V. Detecting and Measuring Radioactivity

A. Because the radiations from radioactive elements are invisible, special instruments are necessary to detect and measure these radiations.

B. It is important that these instruments be very sensitive and very accurate.

1. These radiations can be very harmful to the human body, and persons who work with or are exposed to radioactive elements use these instruments to learn if they are being affected by the radiations and, if so, the amount of radiation that their bodies have absorbed.
2. These instruments are used by scientists, by prospectors to locate new sources of radioactive materials, and by hospitals and industries that use radioactive materials.

C. One simple method of detecting radiations is to observe their action on special highly sensitive photographic film.

1. Radiations from radioactive materials affect photographic film even though the film has not been exposed to ordinary light.
2. When the film is developed, the film shows darkening.
3. The greater the amount of radiation, the darker the film will be when developed.
4. Persons who work with or near radiations often wear **film badges.**
5. These badges have inside them a small piece of film, which can be removed and developed.
6. From the amount of darkening of the developed film, the amount of radiation that has been absorbed by the person can be detected.

D. Another instrument used to detect and measure radiation is the **electroscope.**

1. An electroscope is an instrument that is commonly used to detect and measure small electrical charges.
2. When radiations from radioactive materials pass through air, they cause the particles of air to become electrically charged.
3. The electroscope detects and measures these electrically charged particles of air, and in this way also detects and measures radiations.
4. A type of electroscope, called a **dosimeter,** looks like a pencil, and is clipped to a person's lapel or breast pocket.
5. When the person looks at the dosimeter, he can tell readily whether or not he has been exposed to radiations.

E. The most common instrument used to detect and measure radiations is the Geiger **counter.**

1. This instrument is a cigar-shaped tube made of glass and metal, with a wire running through it, connected to a storage battery and a loudspeaker or amplifier.
2. When the Geiger counter is brought near a radioactive material, the radiations cause a small, pulselike flow of electricity to take place inside the tube.
3. This tiny electric current is amplified, and either produces a series of "clicks" or makes a neon lamp flash on and off.
4. Normally, a Geiger counter produces 25 to 50 clicks a minute even without being near a radioactive material.
5. These clicks come from cosmic rays passing through the air, and also from natural radioactivity in the ground.
6. But, when a radioactive material is present, the Geiger counter clicks very rapidly and produces a "machine gun" effect.
7. Geiger counters are used by prospectors when hunting uranium ore, and are also used in laboratories where radioactivity is being studied.

F. The particles that make up radiations are invisible, but their paths can be seen and photographed in a **cloud chamber.**

1. The cloud chamber is filled with air that is saturated with water vapor.
2. When the particles pass through the chamber, the water vapor condenses on them.
3. Although the particles themselves are still invisible, the paths of the condensed moisture, called **fog tracks,** are visible and can be photographed.
4. A fog track is very much like the vapor trail made by a jet plane flying so high that it is invisible.
5. You can see the path of the invisible plane by the vapor trail it leaves behind, just as you can see the path taken by the invisible particle in the cloud chamber.

VI. Nuclear Fission

A. After scientists learned how uranium, radium, and other radioactive elements break up naturally to form new lighter elements, they decided to try to break up atoms.

B. They began by bombarding atoms of simpler elements with all kinds of high-speed particles.

1. These particles included protons, electrons, alpha particles (the nuclei of helium atoms), and deuterons (the nuclei of hydrogen atoms with a proton and a neutron in them).
2. With the exception of the electrons, all the other high-speed particles are positively charged.
3. The high speeds were given to these particles by instruments commonly called "**atom smashers.**"
4. These "atom smashers" were able to give the particles speeds as high as 150,000 miles a second as well as tremendous amounts of energy.
5. In the "atom smasher" called the **cyclotron,** protons or deuterons are made to whirl around faster and faster in a spiral path until they finally shoot out of the cyclotron at tremendous speed.
6. Other "atom smashers" used to give high speeds to positively charged particles include the **cosmotron,** the **syncreton,** and the **linear speed accelerator.**
7. The **betatron** is an "atom smasher" used to get high-speed electrons.

C. When scientists bombarded the nuclei of atoms of simple elements with the high-speed particles, new elements were formed.

1. A particle would enter the nucleus of an atom and make the nucleus unstable.
2. The unstable nucleus would then rearrange itself by giving off a proton or a neutron, forming a new element, and releasing much energy.
3. This nuclear energy is produced when a small amount of the element's matter is changed into large amounts of energy, in accordance with Einstein's formula of $e = mc^2$.
4. When scientists bombarded nitrogen with high-speed alpha particles (helium nuclei), oxygen and neutrons were formed.
5. When lithium was bombarded with high-speed protons, two alpha particles (helium nuclei) were formed.
6. When beryllium was bombarded with high-speed alpha particles, carbon and neutrons were formed.
7. The scientists had finally found a way to change one element into another.

D. However, scientists were dissatisfied with these high-speed particles.

1. The protons, deuterons, and alpha particles had to be given tremendous amounts of energy before they could enter the nucleus of an atom.
2. This high energy was necessary because these particles were all positively charged, and, when they came near the nucleus of an atom, they were repelled by the same kind of positive charges that the protons in the nucleus had.
3. On the other hand, although the electrons were negatively charged and were

attracted to the positively charged protons in the nucleus, the electrons were so light that it was hard for them to break up the atom.

E. As a result, as soon as the scientists learned how to obtain neutrons by bombarding beryllium with high-speed alpha particles, they began to use neutrons to bombard the nuclei of atoms of the elements.
   1. The neutrons were much better particles to use because they were neutral and would not be repelled by the positively charged nucleus of an atom.
   2. At first the scientists used high-speed neutrons.
   3. However, they soon learned that, because atoms were mostly empty space and because the nucleus is very small compared to the rest of the atom, too often these high-speed neutrons would go right through the atom without striking the tiny nucleus.
   4. They discovered that when they slowed down the neutrons, the slowed-down neutrons were now more likely to hit the nucleus.
   5. In fact, the slowed-down neutrons seemed to behave as if they were attracted to the nucleus, and would go straight to the nucleus.
   6. One of the ways commonly used to slow down the neutrons is to allow them to pass through graphite, which is a form of carbon.
   7. The graphite is called a **moderator** because it slows down or moderates the speed of the neutrons.

F. When scientists began to bombard the atoms of heavy elements with neutrons, a strange thing happened.
   1. When they bombarded uranium with slowed-down neutrons, it did not break up like the lighter elements, giving off a proton or a neutron and forming a new element.
   2. Instead the uranium atom split into two parts, forming an atom of barium and an atom of krypton, both having medium atomic weights.
   3. In addition, two or three neutrons were given off, together with radiations in the form of gamma rays.
   4. Also, more energy was given off than had ever been done before.
   5. This energy was formed when a small amount of the matter in the nucleus of the uranium atom was changed into large amounts of energy.
   6. Scientists called splitting of the nucleus of the atom **nuclear fission.**

G. Because the uranium atom released two or three neutrons when it split, scientists hoped that a continuous splitting up of uranium atoms would be produced.
   1. These two or three neutrons could split more uranium atoms, which would release more neutrons, which could split even more uranium atoms.
   2. In this way a continuous splitting, called a **chain reaction,** would take place and would continue until all the uranium atoms were split.

H. However, the scientists found that only a few uraniums would split, and then the splitting would stop.

I. One reason for the failure to produce a chain reaction was caused by the uranium itself.
   1. The uranium used had two isotopes: uranium-235 with 143 neutrons in its nucleus, and uranium-238 with 146 neutrons in its nucleus.
   2. The uranium-235 isotope splits up very easily, but the uranium-238 isotope does not.
   3. More than 99 percent of the element uranium is made up of the uranium-238 isotope, and less than 1 percent is made up of the uranium-235 isotope.
   4. So, for a chain reaction to take place, the uranium-235 isotope must be separated from the uranium-238 isotope, and only the uranium-235 isotope used.

J. A second reason for the failure of a chain reaction to take place had to do with the

amount of uranium being used in the reaction.

1. If too small an amount of uranium is used, the released neutrons from the fission of one of the uranium atoms will go right through without striking any other uranium atoms, and the reaction stops.
2. Enough uranium must be present so that the neutrons will strike other uranium atoms and keep the chain reaction going.
3. The right amount of uranium needed to keep a chain reaction going is called the **critical size**.

K. Because so little uranium-235 is available, scientists began looking for other more easily available elements that could be split by neutrons.

1. They discovered that they could change the more common uranium-238 isotope into a new element that could be split by neutrons.
2. When uranium-238 atoms were bombarded with neutrons, each nucleus kept a neutron and became unstable, giving off a beta particle (an electron) and forming a new man-made element, called *neptunium*, with an atomic number of 93.
3. Neptunium is an unstable element, and gives off a beta particle too, forming a second man-made element, called *plutonium*, with an atomic number of 94.
4. Plutonium is comparatively stable, but when bombarded by neutrons it splits up just as easily as uranium-235 to produce a chain reaction.

VII. The Atomic Bomb

A. The first atomic bomb was tested at Alamogordo, New Mexico, on July 16, 1945.

1. The bomb had two separate pieces of uranium-235, each piece smaller than the critical size needed to produce a chain reaction.
2. At the exact moment when the explosion was scheduled to take place, the two pieces of uranium-235 were brought together, making just one piece of uranium equal to or larger than the critical size.
3. A chain reaction then took place, producing a tremendous explosion and releasing vast amounts of energy.

B. On August 6, 1945, an atomic bomb, also containing uranium-235, was dropped on Hiroshima, Japan.

C. Three days later an atomic bomb containing plutonium was dropped on Nagasaki, Japan.

D. There are four main effects produced by an atomic bomb.

E. One effect of an atomic bomb is the **shock wave**, or explosive effect.

1. An atomic bomb destroys everything within ½ mile in any direction from where it lands.
2. Severe damage can be found as far as 1 mile from where it lands.
3. Some damage can be found as far as 2 miles from where it lands.

F. A second effect of an atomic bomb is the **heat radiation**, or flash effect.

1. On the spot where the bomb lands, the surface of materials will be heated as high as 5500 degrees Fahrenheit.
2. Serious burns and fires can be found as far as 1 mile from where the bomb lands.
3. A noticeable amount of heat can be detected even 2 miles away from where the bomb lands.
4. Persons looking at the explosion 30 to 40 miles away will be temporarily blinded.

G. A third effect of an atomic bomb is the **nuclear radiations** given off.

1. Nuclear radiations, such as gamma rays and neutrons, destroy living tissue.
2. This kind of damage is quite severe as far as ½ mile in all directions from where the bomb lands.
3. The damage is still severe, but much less so, as far as 1 mile from where the bomb lands.

H. The fourth effect of an atomic bomb is the **radioactive fallout**, or radioactivity that remains after the explosion.

1. The nuclear explosion can blow radioactive particles high into the stratosphere, more than 30,000 feet above the earth's surface.
2. These particles may stay in the air for as long as 10 years.
3. During that time they will spread evenly throughout the stratosphere over all parts of the earth.
4. Eventually these particles will fall back to the earth's surface as a radioactive shower, or fallout.
5. The more nuclear explosions that take place, the greater the concentration of these radioactive particles throughout the stratosphere will be, and the more dangerous the radioactive fallout is likely to become.
6. A shower of highly radioactive particles can produce severe, or even fatal, burns.
7. If the particles fall on food and water, the tissues inside the body will be damaged when the food is eaten or the water is drunk.
8. Radiations may also cause changes in hereditary characteristics that are handed down from one generation to the next.
9. The radioactive isotope strontium-90, produced in some nuclear explosions, has a half-life of 22 years, and may affect humans quite harmfully in an indirect way.
10. Strontium is an element that is very similar to the element calcium and, like calcium, is deposited in the bones of our body.
11. Strontium-90 may fall to earth and be taken up from the soil by plants, which are then eaten by cows and other animals.
12. When a person drinks milk or eats meat, the strontium-90 may be deposited in his bones, giving off radiations that may eventually produce bone cancer or leukemia, both of which are usually fatal.

VIII. Controlling and Using Nuclear Energy

A. Man has learned how to control and use nuclear energy by using a device called a **nuclear reactor**, which is sometimes also called an **atomic pile.**

B. The nuclear reactor helps us keep a chain reaction under control, and makes use of the energy produced as a result of this reaction.

C. The reactor acts somewhat like a large oven or furnace.

1. In the reactor there is a large block of graphite, which acts as a moderator to slow down the neutrons so that they can enter the nuclei of the uranium-235 and produce a chain reaction.
2. Rods of uranium-235, sealed in aluminum cans for protection, are put into holes running horizontally through the graphite block from one end to the other.
3. Boron-steel or cadmium-steel rods are inserted into holes at the top of the reactor and run vertically through the graphite block.
4. These steel rods, called **control** rods, can be moved in and out of the reactor, and in this way control the speed of the chain reaction.
5. The control rods absorb any neutrons that hit them.
6. If the chain reaction is going too fast, the control rods are lowered further into the reactor so that they can absorb more neutrons and thus slow down the reaction.
7. If the reaction is going too slow, the rods are lifted farther out of the reactor so that less neutrons are now absorbed, and the reaction can speed up.
8. In some reactors the tremendous amount of heat that is produced is removed by blowing air through circulating tubes in the reactor.
9. In other reactors the heat is removed by water or some other liquid passing

through the circulation tubes in the reactor.

10. The entire reactor is enclosed in a thick layer of solid concrete, which absorbs any dangerous radiations and therefore helps protect the persons operating the nuclear reactor.

D. The heat produced from the nuclear reaction is used to boil water and change the water into steam.

1. The steam then turns a turbine, which runs an electric generator that produces electricity.
2. After the steam passes through the turbines, it is condensed and returned to the boilers to be changed back into steam again.

E. Nuclear reactors are now being used to run submarines and ships.

1. Vessels driven by the power from nuclear reactors can sail for long distances without having to refuel.
2. The first nuclear submarine, the *Nautilus,* traveled almost 60,000 miles before it had to refuel.

IX. Radioactive Isotopes

A. Only a few of the 92 elements found on earth are naturally radioactive.

B. Most of the naturally radioactive elements are the heavy elements, like uranium and radium.

C. However, scientists discovered that, when they bombarded the other natural elements with neutrons or deuterons (the nuclei of hydrogen atoms with a proton and a neutron in them), radioactive isotopes of these elements are formed.

1. By using either the nuclear reactor or the cyclotron and other "atom smashers," radioactive isotopes of practically all the elements have now been prepared.
2. These man-made radioactive isotopes are more commonly called **radioisotopes.**

D. These radioisotopes have been most helpful in medicine, industry, agriculture, and research.

1. Because they all give off radiations that can be detected by such instruments as the Geiger counter, they can be used as tracers in many different ways.
2. They can be traced as they move through pipelines, to detect leaks in the pipes.
3. They can be used to study the wear of machine parts or automobile treads.
4. They can also be used to study refining processes in oil refineries, detect flaws in metal parts, and gauge the thickness of sheets of metal, rubber, plastic, cloth, and paper.

E. Radioactive carbon can be used to show how the leaves of green plants make food for the plant by photosynthesis.

1. The radioactive carbon is burned to form carbon dioxide gas.
2. This carbon dioxide is added to the air that the plant is using.
3. The atoms of radioactive carbon in the carbon dioxide gas are traced while the different steps in the process of photosynthesis take place in the leaves and the rest of the plant.

F. Radioisotopes are being used to tell how well the plant is making use of fertilizers that have been added to the soil.

1. For example, radioactive phosphorus is mixed with fertilizer that has phosphorus in it.
2. The Geiger counter traces the radioactive phosphorus that has gone from the soil into the plant, and measures the amount of phosphorus that the plant used.

G. The exposure of seeds and plants to radiations from radioisotopes is producing new and better varieties of plants.

H. Radioactive cobalt is now being used to treat cancer instead of radium because it is easily made, is cheaper, and is more satisfactory.

I. Radioactive phosphorus and arsenic are being used to detect brain tumors.

1. This detection is possible because the brain tumor picks up more of these ra-

dioactive elements than the normal brain tissue around the tumor.

2. These extra amounts of radioactive elements in the tumor are detected by the Geiger counter.
3. Another radioisotope, radioactive boron, is now being used to treat these brain tumors.

J. Radioactive iodine is used to detect diseases of the thyroid gland.

1. This detection is possible because most of the iodine taken in by the body goes to the thyroid gland.
2. When radioactive iodine is taken into the body, its path to the thyroid gland is traced by a Geiger counter.
3. If the Geiger counter shows that the gland has taken up very little of the radioactive iodine, doctors know that the gland is not working actively or normally.
4. On the other hand, if the gland takes up too much radioactive iodine, doctors know that the gland is overactive.
5. Radioactive iodine is also used to treat cancer of the thyroid gland.

K. Radioisotopes are used by chemists to discover how chemical changes take place, and to learn more about the structure and properties of matter.

X. Nuclear Fusion and the Hydrogen Bomb

A. In nuclear fission, energy is obtained by getting the nucleus to break up or split in two.

1. The atomic bomb and the nuclear reactor, or atomic pile, get their energy this way.
2. The amount of energy we can get from nuclear fission is definitely limited because the size of each portion of radioactive material in the atomic bomb is limited.
3. Each portion must not be greater than the critical size needed to produce a continuous chain reaction.

B. Scientists have discovered that they can get even more energy by joining atoms together rather than by splitting them.

1. They found a way to combine lighter atoms to form heavier atoms.
2. They combined the nuclei of lighter atoms to form heavier, more stable nuclei.
3. In the process, vast amounts of energy were given off because some of the matter of the lighter atoms was changed into energy when the atoms were joined together.
4. This method of joining nuclei of atoms together is called **nuclear fusion.**

C. The **hydrogen bomb,** also called the **H-bomb** and the **thermonuclear bomb,** gets its energy from a nuclear fusion reaction.

D. One way to get a hydrogen bomb to explode is to begin with a compound of lithium and hydrogen, called lithium hydride.

1. The hydrogen used in this compound is deuterium, an isotope of hydrogen having a proton and neutron in its nucleus.
2. Ordinarily, in a molecule of lithium hydride, the lithium and hydrogen nuclei are held apart by the shells or energy levels that surround them.
3. However, when the temperature becomes millions of degrees hot, and when there is very great pressure, the nuclei of the lithium and hydrogen atoms are fused together, forming two alpha particles (helium nuclei) and releasing tremendous amounts of energy.
4. An atomic bomb is used to get this very high temperature and pressure, which sets off the hydrogen bomb.

E. Another way to get a hydrogen bomb to explode is to use deuterium and tritium, which are both isotopes of hydrogen.

1. Deuterium has a nucleus with a proton and a neutron in it, and tritium has a nucleus with a proton and two neutrons in it.
2. Under very high temperature and pressure, the deuterium and tritium combine to form a helium atom and a neutron, and vast amounts of energy are released.

3. An atomic bomb is also used in this reaction to get the temperature and pressure high enough to set off the hydrogen bomb.

F. A hydrogen bomb can be and is much more destructive than an atomic bomb.
   1. First, more matter is changed into energy when there is a fusion reaction, so much more energy is released.
   2. Second, there is no limit to the size of a hydrogen bomb, so the amounts of materials used in the hydrogen bomb are much greater and the explosive power is thousands of times more powerful.

XI. Man-Made Elements

A. By using the radiations from the nuclear reactor or from the cyclotron and other "atom smashers," scientists have been able to prepare radioactive isotopes of practically all of the 92 natural elements found on earth.
   1. These radioactive isotopes may be new, but they are not new elements.
   2. They are only new forms of already known elements.

B. However, scientists have also been able to use the nuclear reactor and the "atom smasher" to create entirely new elements as well.
   1. All of these new elements have a higher atomic number than uranium, the ninety-second natural element.
   2. They are all radioactive, and some of them have a long half-life, but others have a half-life that lasts for just a few seconds.

C. At present there are 11 new man-made elements, as shown in Table 16–4.

Table 16–4. Eleven New Man-Made Elements

NAME	SYMBOL	ATOMIC NUMBER	SOURCE OF NAME
Neptunium	Np	93	The planet Neptune
Plutonium	Pu	94	The planet Pluto
Americum	Am	95	America
Curium	Cm	96	Marie Curie
Berkelium	Bk	97	University of California at Berkeley
Californium	Cf	98	University and State of California
Einsteinium	Es	99	Albert Einstein
Fermium	Fm	100	Enrico Fermi, Italian nuclear physicist
Mendelevium	Md	101	Dmitri Mendeleyev, Russian chemist
Nobelium	No	102	Alfred B. Nobel
Lawrencium	Lw	103	Ernest O. Lawrence, inventor of the cyclotron

LEARNING ACTIVITIES FOR "CHANGES IN MATTER AND ENERGY"

THE STRUCTURE OF MATTER

1. *Matter* · Show that solids, liquids, and gases are forms of matter because they occupy space and have weight. A book or a uniform block of wood are solids that can be measured and weighed easily. Pouring water into a glass jar will show that a liquid occupies space, and weighing the jar before and after pouring will show the liquid has weight. Repeat Learning

Activities 11 and 12 of "Air," Chapter 12 (p. 419) to show that air, a gas, occupies space and has weight. Also, the children can make a list of different common materials that can be found in school or at home.

2. *The states of matter* · Refer to Learning Activity 1 above to show that a solid has a definite size and shape, and that a liquid has a definite size but not a definite shape. Pump air into a deflated bicycle tire to show that a gas does not have a definite size or shape, but spreads out until it has the same size and shape of its container.

Place some ice cubes in a Pyrex container and allow them to melt. Then heat the water until it boils. Point out the changes in state that have taken place. Have the children make a list of familiar changes in state that take place around them.

3. *Weight and mass* · Repeat Learning Activity 5 of "The Solar System," Chapter 9 (p. 276), showing the earth's pull of gravity. Relate the earth's pull of gravity to the concept of weight. Compare weights on earth with weights on the moon, where the moon's pull of gravity is only one sixth that of the earth. Point out that in all cases the mass does not change, but remains the same.

4. *Center of gravity* · Have a child balance a uniform object, such as a yardstick, on the tip of one finger. Note that the point where the yardstick balances is where the center of gravity is located. Now make the yardstick unsymmetrical by putting some modeling clay along one end. Have the child balance the yardstick again, and note that the center of gravity has shifted toward the thicker, and heavier, part of the yardstick.

5. *The properties of matter* · Have the children bring in a variety of materials from home, and ask them to describe some of their physical properties. Such properties could easily include size, shape, color, texture, density (heaviness or lightness), odor, taste, and solubility in water.

6. *Physical and chemical changes* · Cut up a piece of paper or wood into small pieces, and then burn the paper or wood. Note that cutting the paper or wood is a physical change, but burning the material is a chemical change. Compare the basic differences between physical and chemical changes.

7. *Molecular motion* · Place a spoon into a cup of hot water. Point out that the part of the spoon above the water becomes hot because of molecular motion. The heat of the water makes the molecules in that part of the spoon below the water move faster, and so the spoon becomes hot. These faster moving molecules strike nearby molecules in that part of the spoon above the water, making them move faster too. Soon this faster molecular motion is transmitted throughout that part of the spoon above the water, and that part becomes hot too.

Allow a drop of food coloring to fall into a tumbler of cold water. The motion of the molecules of water disperses the coloring throughout the tumbler. Repeat the experiment, using hot water instead. Note how the faster moving molecules of hot water disperse the coloring more quickly.

Pour some inexpensive strong perfume on a piece of absorbent cotton. Place the cotton in a dish at one end of the room, and have the children raise their hands as soon as they smell the perfume. Point out that the perfume evaporates, and the molecules of perfume vapor then travel across the room.

8. *Cohesion and adhesion* · Allow a drop of water to fall on a mirror or piece of glass. Point out that the drop of water remains intact because of the cohesion of the water molecules, whereas the water adheres to the glass because of adhesion.

9. *Atomic structure* · Tape a sheet of white paper on a piece of corrugated cardboard. Draw a small circle to represent the nucleus of an atom. Draw concentric circles to represent the shells or energy levels of the electrons outside the nucleus. Now use thumbtacks of three differ-

ent colors to represent the number of electrons, protons, and neutrons in an atom of aluminum (Figure 16–1). Place 13 protons and 14 neutrons in the nucleus, and position 13 electrons in the concentric circles as shown in the diagram. Try making similar representations for other common atoms. Point out that the atom is really three dimensional.

Have the children look at a table that provides the atomic numbers and atomic weights of several or all of the elements. Such a table can be found in any high school or college chemistry textbook. Let the children use these values to determine the number of electrons, protons, and neutrons in atoms of some of the well-known elements.

10. *Isotopes* · Use diagrams or models to develop the concept of an isotope. Point out the complete similarity between isotopes of the same element except for the difference in number of neutrons.

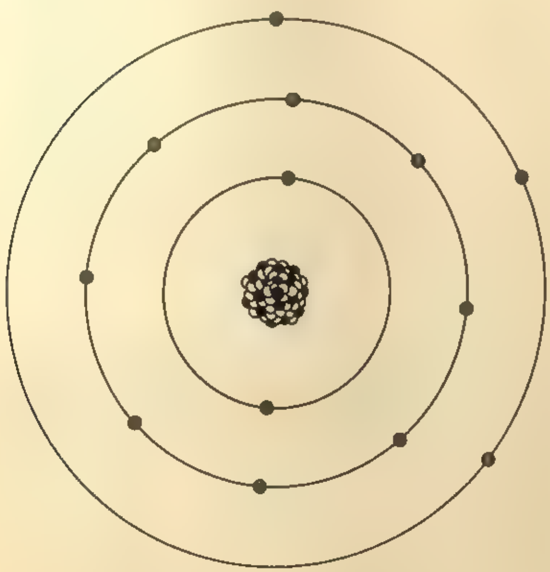


FIGURE 16–1.
ATOMIC STRUCTURE OF AN ALUMINUM ATOM.

11. *Elements* · Make a collection of easily available elements such as iron, copper, silver, gold, aluminum, magnesium, tin, zinc, carbon, and sulfur. (The evaporation of tincture of iodine will also provide the element iodine.) Point out that all the atoms of an element are the same, but the atoms of one element are different from atoms of other elements.

Divide the elements into two groups: metals and nonmetals. Make a list of all the properties that metals have in common. List some of the ways that metals differ from each other. Compare the differences between metals and nonmetals.

12. *Symbols* · Have the children make an alphabetical list of all well-known elements and their symbols. Such information can be found in a chemistry textbook or an encyclopedia. Note how the symbols in most cases provide a clue to the name of the element. Where the symbol does not correspond with the name of the element, have the children find out from the encyclopedia the element's name in another language, from which the symbol was derived.

13. *Mixtures* · Make a mixture containing fine sand, sugar, iron filings, bits of cork filed from a cork stopper, and small marbles. Have the children think of and suggest ways and means of separating the components of the mixture. They should conclude that the marbles can be removed by hand or by pouring the mixture through a kitchen strainer. The iron filings can be removed with a strong magnet. Adding water to the remaining part of the mixture and then stirring causes the sugar to dissolve and the bits of cork to float on top of the solution. The bits of cork can be removed with a large spoon. Pour off the solution, leaving the sand behind. Now allow the solution to evaporate in a pie tin or other shallow container; this action causes the sugar to be left behind.

14. *Compounds* · Make a mixture consisting of two parts powdered sulfur and one part iron filings. Stir until the mixture is quite uniform

and the ingredients are quite undistinguishable. Place one half of the mixture in a shallow dish, and use a strong magnet to separate the iron from the sulfur, showing that the materials in a mixture retain their own special properties and can usually be separated by very simple means. Pass the magnet over the sulfur several times, to pick up all the iron filings.

Now pour the second half of this mixture of sulfur and iron filings into a Pyrex tube that is supported on a ring stand by a clamp (Figure 16–2). Heat the test tube with a Bunsen burner,

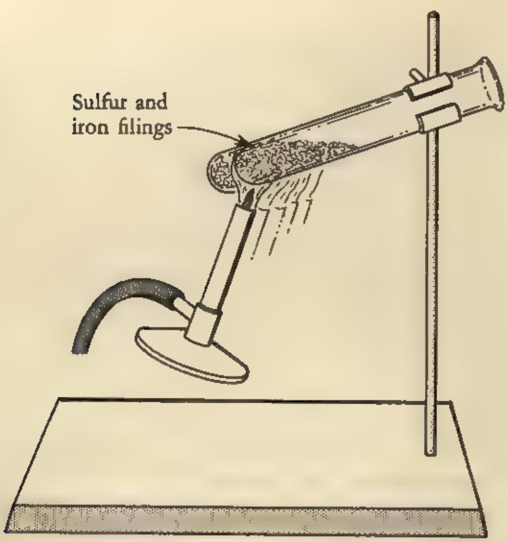


FIGURE 16–2.
HEATING SULFUR AND IRON WILL PRODUCE A COMPOUND.

first gently and then strongly. Keep moving the flame up and down the lower half of the test tube to make sure the contents are being heated uniformly. Soon the contents will begin to glow, showing that a chemical change is taking place. Remove the flame and observe that the chemical change continues to take place, with the contents glowing strongly. Allow the test tube to cool to room temperature, wrap the tube in a piece of cloth or toweling, and break the end of the test tube gently with a hammer. Remove the contents with tweezers and place the material in a shallow dish. Try to separate the iron filings with a magnet. Nothing will happen because a new substance, called iron sulfide, has been formed and it is not magnetic.

15. *Chemical formulas* · Write on the chalkboard the names and chemical formulas of such common materials as salt, sugar, vinegar, rubbing alcohol, hydrogen peroxide, and sodium bicarbonate. Have the children name the elements in each formula and state how many atoms of each element are present.

16. *Types of chemical changes* · To show combination, repeat Learning Activity 4 of "Air," Chapter 12 (p. 418). Remove the wad of steel wool and examine the rust under a magnifying glass. Notice how the dark, metallic iron threads have been changed into the reddish-orange, powdery iron oxide. Soak another wad of steel wool in water and leave it exposed to the air for a few days until it has become quite rusty. Scrape off some of the rust and see if it can be attracted by a magnet.

To show decomposition, pour some hydrogen peroxide into a large tumbler or small glass jar. Add about a teaspoon of manganese dioxide into the glass container and cover the top with an index card or piece of cardboard. The bubbling shows that hydrogen peroxide is decomposing into water and oxygen gas. When the bubbling subsides, insert a glowing splint into the jar. The splint will burst into flame, showing the presence of oxygen.

To show simple replacement, dissolve some copper sulfate crystals in a beaker or tumbler of water and stir until the copper sulfate dissolves completely. Place one or two iron nails in the solution and allow them to stay overnight. Remove the nails, dry them with a soft cloth, and examine the coating of copper on them. Point out that some iron from the nails replaced the copper from the solution of copper sulfate.

To show double replacement obtain a small amount of dilute silver nitrate solution from the drugstore. Dissolve some table salt (sodium chloride) in a glass tumbler or beaker half-

filled with water. Pour the clear silver nitrate solution into the equally clear salt solution. A white solid, or precipitate, forms immediately. Point out that the silver nitrate and sodium chloride interact to form silver chloride and sodium nitrate. The sodium nitrate remains in solution whereas the silver chloride comes out of solution as the insoluble white solid.

17. *Solutions* · Obtain three water tumblers of the same size. Fill each tumbler about three-quarters full of tap water of the same temperature. To one tumbler add ¼ teaspoon of sugar and stir until all the sugar is dissolved. To the second tumbler add 2 teaspoons of sugar and stir until all the sugar is dissolved. Taste both solutions and note which is dilute and which is concentrated.

To the third tumbler add ½ teaspoon of sugar and stir until all the sugar is dissolved. Continue adding sugar, ½ teaspoon at a time and stirring after each addition, until no more sugar will dissolve and a small pile of undissolved sugar remains at the bottom of the tumbler. Total the number of teaspoons of sugar you added to obtain a saturated sugar solution.

18. *Some substances are more soluble in water than others* · Add equal amounts of water of the same temperature to each of three test tubes. Add a level teaspoon of sugar to one test tube, a level teaspoon of salt to the second test tube, and a level teaspoon of sodium bicarbonate to the third test tube. While placing your thumb over the mouth of the test tube, shake each test tube vigorously ten times, and then place the test tubes upright and allow any undissolved material to settle. Note the degree of solubility of the three different materials.

19. *Some substances are insoluble in water* · Place a small stone or some sand in a test tube of water. Place your thumb over the mouth of the test tube and shake the tube vigorously. No dissolving will take place.

Add a few drops of oil to a test tube containing water. The oil will float on top of the water. Shake the test tube vigorously. Although the oil may break up into small drops, the drops will reassemble and the oil will continue to float undissolved on top of the water. Repeat the experiment, using carbon tetrachloride instead of water. This time the oil will be dissolved.

20. *Effect of temperature on the solubility of solids in liquids* · Pour a measured amount of water at room temperature into a tumbler or beaker. Add sugar, a teaspoon at a time and stirring after each addition, until no more will dissolve. Repeat the experiment, using an equal amount of hot water this time. Compare the number of teaspoons of sugar that dissolved in the cold and hot water, respectively.

21. *Effect of pressure on the solubility of gases in liquids* · Obtain two identical bottles of soda pop. Place one bottle in the refrigerator and allow it to stand overnight. Keep the other bottle at room temperature. The next day remove the caps from both bottles. Place the cold, open bottle back in the refrigerator, and let the warm, open bottle stand again at room temperature. At the end of an hour pour the contents of both bottles into each of two tumblers. The soda pop from the cold bottle will fizz fairly vigorously, showing the presence of dissolved gas. The soda pop from the warm bottle will fizz weakly, if at all, showing that most of the dissolved gas has been driven from the pop by the increase in temperature.

22. *Ways of making solids dissolve more quickly in water* · Pour equal amounts of water at the same temperature into two tumblers or beakers. Obtain two cubes of sugar and crush one of the cubes into small crystals. Place the lump of sugar in one tumbler and the crushed sugar in the second tumbler. Stir the water in each tumbler vigorously. The crushed sugar will dissolve more quickly because more of the water can come in contact with the sugar at one time.

Pour equal amounts of water at the same temperature into two tumblers. Add a level teaspoon of sugar to each of the tumblers. Stir the water in one of the tumblers. The sugar in the stirred water will dissolve more quickly because the stirring helps spread the sugar more quickly throughout the water and at the same time brings fresh parts of the water in contact with particles of sugar that have not yet dissolved.

Pour a measured amount of water at room temperature into a tumbler. Pour an equal amount of hot water into a second tumbler. Drop a sugar cube into each tumbler and note how much more quickly the sugar dissolves in the hot water.

ENERGY

1. *Kinetic energy* · Have the children look for and make a list of common examples of kinetic energy in their everyday life. Wherever possible, let them show how these moving bodies can do work.

2. *Potential energy* · Holding a book poised in midair will show the potential energy a body will have because of its position. Stretching a rubber band or squeezing together the ends of a spring coil will show the potential energy a body will have because of its condition. Have the children look for and list other everyday examples of potential energy.

3. *Convert potential energy into kinetic energy* · Drop the book and release the rubber band and spring coil described in Learning Activity 2 above. Note that the energy of position or condition (potential energy) has now been changed into energy of motion (kinetic energy).

Obtain or have one of the children bring in a paddle-ball toy, which consists of a wooden paddle connected in the center to a rubber ball with a long, single rubber band. Let the child work the toy. Point out that this is an example of a constant conversion of kinetic energy to potential energy and back again. The paddle strikes the ball, making it move out and giving it kinetic energy. As the ball moves, the rubber band stretches. Kinetic energy is now being converted to potential energy. When the ball has moved out as far as it can, it stops for a fraction of a second before it begins its return to the paddle. At this moment all the kinetic energy of the moving ball has been converted to the potential energy of the stretched rubber band. The ball travels back toward the paddle, and the potential energy is now being converted back to kinetic energy again. This same situation can be shown with a yo-yo as well.

4. *Forms of energy and their transformation* · Write the six different forms of energy on the chalkboard and have the children list examples of how each form is used. Then have the children give examples of how energy can be changed from one form to another.

NUCLEAR ENERGY

1. *Radioactivity* · Obtain a magnifying glass and wrist watch or alarm clock that has a luminous dial. Go into a completely darkened room and wait until your eyes become completely accustomed to the darkness. Hold the dial a few inches from one eye and adjust the distance until you see tiny bursts or flashes of light being given off from the numbers and hands of the dial. Now examine the phenomenon under the magnifying glass. Point out that the hands and numbers of the dial are coated with a paint that contains a material, such as zinc sulfide, and a tiny amount of radium compound. The radium compound breaks up, giving off invisible radiations that strike the zinc sulfide and make it give off these tiny bursts or flashes of light. Each burst of light represents the breaking up of one radioactive particle of the radium compound.

2. *The life of radioactive elements* · On the chalkboard trace the disintegration of a radioactive element, showing the kinds of particles

formed during each step of the disintegration, the changes in atomic weight and atomic number, the new elements formed, and their half-lives. Repeat, using other radioactive elements.

Have the children read about and report on the use of radioactivity to determine the age of rocks and of the earth. Show how a knowledge of the half-life of uranium and of radioactive carbon-14 plays an important role in determining this age.

3. *Detect radiations* · If possible, obtain a Geiger counter or an inexpensive radioactivity indicator. Bring a wrist watch or alarm clock with a luminous dial near the Geiger counter and note the increase in number of clicks. Some of the children's mineral collections or sets will have samples of uranium ore that can be tested with the Geiger counter. Have the children read about and report on other methods or instruments used to detect radiations.

4. *Atom smashers* · Have the children read about and report on such atom smashers as the cyclotron, cosmotron, syncreton, linear speed accelerator, and belatron.

5. *Nuclear fission* · Contrast the slow rate of disintegration of naturally radioactive elements with the tremendously rapid rate of disintegration as a result of nuclear fission. Compare the products and amount of energy produced in each case.

Show the importance of having the right amount, or critical size, of uranium to keep a chain reaction going. Shape a piece of modeling clay into a large circle about ½ inch thick. Insert wooden matches into the clay so that they stand upright, placing the matches so that each one is about 1½ or 2 inches away from the other. Light one match located at the edge of the circle. It will burn without setting the other matches on fire. Replace this burnt match and then insert more matches until each match is only ½ inch away from the other. Now light one match, and it will produce a "chain reaction" by igniting all the others very quickly.

6. *Controlling nuclear energy* · Obtain pictures, draw diagrams, or construct a model of a nuclear reactor. Discuss the parts of the reactor, their functions, and the method of controlling the rate of fission. Make a list of the actual and potential uses for nuclear reactors.

7. *Man-made isotopes and elements* · Discuss the formation of radioisotopes. Have the children read about and report on their uses in research, medicine, industry, and agriculture. Have one group of children make up a list of the man-made elements, which includes the name of each element, its symbol, the atomic number, the atomic weight, and the person or object after which the element was named.

8. *The atom bomb and hydrogen bomb* · Discuss and compare the difference between fission and fusion. List the materials used in each case and describe the products that are formed. Contrast the atom and hydrogen bombs, including the amounts of energy released and potential destructiveness. Have the children read about and report on radioactive fallout and its inherent dangers.

BIBLIOGRAPHY FOR "CHANGES IN MATTER AND ENERGY"

AZIMOV, ISAAC. *Building Blocks of the Universe.* New York: Abelard, 1957. 256 pp.

———. *Inside the Atom* (rev. ed.). New York: Abelard, 1958. 185 pp.

BLACKWOOD, PAUL E. *Push and Pull: The Story of Energy.* New York: McGraw, 1959. 190 pp.

BRANLEY, FRANKLYN M. *Solar Energy.* New York: Crowell, 1957. 118 pp.

CARONA, PHILIP. *The True Book of Chemistry.* Chicago: Childrens, 1962. 47 pp.

COOPER, ELIZABETH K. *Discovering Chemistry.* New York: Harcourt, 1959. 190 pp.

DUTTON, WILLIAM G. *One Thousand Years of Explosives: From Wildfire to the H-Bomb.* New York: Holt, Rinehart & Winston, 1960. 183 pp.

FARADAY, MICHAEL. *The Chemical History of a Candle.* New York: Crowell, 1957. 158 pp.

FREEMAN, MAE, and IRA FREEMAN. *The Story of the Atom.* New York: Random, 1960. 82 pp.

GALLANT, ROY. *Exploring Chemistry.* New York: Doubleday, 1958. 120 pp.

HABER, HEINZ. *Our Friend the Atom.* New York: Simon & Schuster, 1956. 165 pp.

HOGBEN, LANCELOT. *The Wonderful World of Energy.* New York: Doubleday, 1957. 69 pp.

HYDE, MARGARET O. *Atoms Today and Tomorrow.* New York: McGraw, 1959. 159 pp.

IRVING, ROBERT (pseud. of Irving Adler). *Energy and Power.* New York: Knopf, 1958. 140 pp.

IRWIN, KEITH G. *The Romance of Chemistry.* New York: Viking, 1959. 148 pp.

KEEN, MARTIN L. *The How and Why Wonder Book of Chemistry.* New York: Grosset, 1961. 48 pp.

LANDIN, LES. *Atoms for Junior.* Chicago: Childrens, 1961. 32 pp.

LEWELLEN, JOHN. *The Mighty Atom.* New York: Knopf, 1955. 58 pp.

MEYER, JEROME S. *Picture Book of Chemistry.* New York: Lothrop, 1957. 40 pp.

PARKER, BERTHA M. *Gravity.* New York: Harper, 1959. 36 pp.

———. *Matter, Molecules, and Atoms.* New York: Harper, 1959. 36 pp.

———. *What Things Are Made Of.* New York: Harper, 1958. 36 pp.

PEARL, CARLETON. *The Tenth Wonder: Atomic Energy.* Boston: Little, 1956. 129 pp.

POSIN, DANIEL Q. *What Is Chemistry?* Chicago: Benefic, 1961. 48 pp.

———. *What Is Energy?* Chicago: Benefic, 1962. 48 pp.

———. *What Is Matter?* Chicago: Benefic, 1962. 48 pp.

RADLAUER, EDWARD, and RUTH SHAW. *About Atomic Power for People.* Chicago: Melmont, 1960. 48 pp.

SEABORG, GLENN T., and EVANS G. VALENS. *Elements of the Universe.* New York: Dutton, 1958. 253 pp.

VICTOR, EDWARD. *Molecules and Atoms.* Chicago: Follett, 1963. 32 pp.

WATSON, JANE WARNER, and BERTHA M. PARKER. *The Everyday Atom.* New York: Harper, 1959. 36 pp.

CHAPTER

17 Friction *and* Machines

FRICTION

I. What Friction Is

A. Whenever the surfaces of two materials rub against each other, there is **friction.**

B. Friction is the force that resists the movement of one material over another material.

C. Some scientists think that friction is caused by the irregularities in the surfaces of materials.

1. Every surface has little bumps and hollows on it.
2. On rough surfaces these bumps and hollows can be seen or felt.
3. On smooth surfaces the bumps and hollows can be seen through a magnifying glass or microscope.
4. When two surfaces are rubbed together, the bumps and hollows catch and stick and resist the movement of the surfaces over each other.

D. Some scientists think that friction is also caused by the attraction of the molecules of one surface to the molecules of another surface as the surfaces rub against each other.

E. Whenever there is friction, heat is produced. The greater the friction, the more heat will be produced.

F. Friction can make it hard to push one material across another material.

II. Factors Affecting Friction

A. The **nature of the materials** affects friction.

1. Firm, hard materials produce less friction than soft, sticky materials.

B. The **nature of the surfaces** affects friction.

1. Smooth surfaces produce less friction than rough surfaces.

C. The **amount of area** between two surfaces affects friction.

1. The larger the area of the surfaces in contact with each other, the greater the friction will be.

D. The **pressure of the two surfaces** against each other affects friction.

1. The greater the force pressing the surfaces against each other, the greater the friction will be.

E. **Sliding friction** is less than **starting friction.**

1. More force is needed to start an object sliding than to keep it sliding.

F. **Rolling friction** is less than sliding friction.

1. In sliding friction the bumps and hollows catch against each other.
2. In rolling friction, the roller or wheel lifts up over the bumps and hollows instead of sliding and catching against them.

III. Methods of Reducing Friction

A. Making the surfaces **smoother** levels out the bumps and hollows and reduces the friction between them.

B. A slippery material, called a **lubricant,** reduces friction.

1. The lubricant is placed between the two surfaces, filling up the hollows and covering the bumps.
2. In this way the lubricant prevents the two surfaces from rubbing directly against each other.
3. Oil is a lubricant used to reduce friction between parts of machines.
4. Grease is used to lubricate parts of an automobile.
5. Glycerine and water can also be used as lubricants to reduce the friction between rubber and glass.
6. Soap or candle wax are used as lubricants to reduce the friction between two pieces of wood, or between wood and metal.
7. Graphite (a form of carbon) can be used to reduce friction between two metals, or to reduce friction between wood and metal.

C. **Rollers, wheels,** or **ball bearings** reduce friction.

1. They change sliding friction to rolling friction.
2. The rollers, wheels, and ball bearings are placed between two materials, making it possible for the surfaces of these materials to roll over each other, and thus reduce friction.

D. An **antifriction** metal reduces friction.

1. Less friction is produced when steel slides over certain kinds of metals than when steel slides over another piece of steel.
2. These metals are called **antifriction** metals because they reduce the amount of friction.
3. Babbitt metal, a mixture of tin, copper, and antimony, is a good "antifriction" metal.

IV. Useful Effects of Friction

A. Friction can be very useful.

B. Without friction, we could not walk because our feet would slip. In the gymnasium we use rubber-soled shoes to increase friction.

C. Sand or cinders are dropped in front of an automobile's rear wheels to increase friction and stop the wheels from spinning on icy roads.

D. Snow-tread tires are wider and have deeper treads than ordinary tires to create more friction.

E. Auto brakes use friction to slow down or stop a moving auto.

F. Friction helps hold nails and screws in wood.

G. Friction helps us unscrew the tops of bottles or jars, and helps us open cans.

H. Friction helps us hold a baseball and bat.

I. In industry, friction helps the conveyor belt move things along.

J. Friction is useful in making things smoother, like sanding wood or grinding lenses.

K. The heat caused by friction makes a match burst into flame.

L. The friction between the flint and the wheel of a cigarette lighter produces a spark that causes the wick to light up.

V. Harmful Effects of Friction

A. Friction wears away things.

1. Automobile tires, shoes, and clothing are worn away by friction.
2. The moving parts of machines rub against each other and gradually wear away.

B. Friction makes work harder because extra force must be used to overcome friction.

C. Friction produces heat, which may be harmful.

1. The heat may cause machine parts to melt and bend.
2. At high speed the friction between the air and a plane or rocket may cause

parts of the plane or rocket to become so hot that they will burn up, melt, or bend.

3. If we fall and slide across the gymnasium floor, the heat produced by the friction between a part of the body and the floor may cause a very painful and easily infected burn.

MACHINES

I. What Machines Do

A. Machines are devices that help make man's work easier.

B. A force must be used to make a machine work. A force is a push or a pull.

C. A force may be produced by the following:
1. Electricity.
2. Steam.
3. Gasoline.
4. Wind.
5. Falling water.
6. Sun's rays.
7. Springs and weights.
8. Muscles.

D. Machines can help us in four different ways.
1. All machines can transfer a force from one place to another.
2. Some machines can increase the amount of a force so that we can lift heavier things or exert more force with the machine than we could alone.
3. Some machines can change the direction of a force so that we can make things move in different directions.
4. Some machines can increase the distance and speed of a force so that we can move things farther or faster.

E. No machine can increase both force and distance at the same time.
1. If only a small force is needed to move or lift a heavy object, there is a gain in force.
2. However, the heavy object will now move or be lifted through a shorter distance.
3. So, although there is a gain in force, there is a loss in distance.

II. The Six Simple Machines

A. All machines—no matter how many parts they have—are made up of one or more simple machines.

B. There are just six simple machines, as follows:
1. Lever.
2. Wheel-and-axle.
3. Pulley.
4. Inclined plane.
5. Wedge.
6. Screw.

C. Actually, the wheel-and-axle and the pulley are different forms of the lever, and the wedge and the screw are different forms of the inclined plane.

III. Work

A. Machines help make work easier, but machines do not save work.

B. According to scientists, work is done only when an effort or a resistance moves through a distance.
1. The force exerted on a machine is called the **effort**.
2. The force that the machine exerts, or the object that the machine lifts or moves, is called the **resistance**.

C. No matter how much effort or resistance is exerted, if they have not moved through a distance, no work has been done.

D. To find out how much work has been

done, the force is multiplied by the distance through which the force moves.

1. This expression can be stated as a formula:

Work = force used × distance moved

2. If the force is stated in pounds, and the distance stated in feet, the work done is expressed in **foot-pounds.**
3. To calculate the work that is put into a machine, multiply the effort times the distance the effort moves.
4. If you exert an effort of 2 pounds that moves through a distance of 5 feet, you have done 2 × 5, or 10, foot-pounds of work.
5. To calculate the work that the machine does or puts out, multiply the resistance times the distance the resistance moves.
6. If a machine lifts an object weighing 5 pounds through a distance of 2 feet, the machine has done 2 × 5, or 10, foot-pounds of work.

E. The speed with which the effort or resistance moves will make no difference in the amount of work done.

F. No machine can produce more work than the amount of work that was put into the machine.

G. If there were no friction, the amount of work that a machine could do or put out would be exactly equal to the amount of work put into a machine.

1. This condition is called the **principle of work.**
2. The principal of work helps explain why a small force must move through a longer distance to make a heavy object move through a shorter distance.

H. Because of friction, however, the amount of work put out by a machine is less than the work put into the machine.

1. Extra effort, which means more work, must be used to overcome friction.
2. The amount of extra effort involved in overcoming friction makes a difference in the efficiency of a machine.

IV. Mechanical Advantage

A. When we use a small force on a machine and the machine gives us more force, or lifts or moves a heavy object, we say we get a **mechanical advantage (M.A.)** of force.

1. If a machine produces a force that is five times as great as the force that is acting on the machine, the mechanical advantage of force is 5.
2. If a machine moves or lifts an object that is five times as heavy as the force acting on the machine, the mechanical advantage of force is 5.

B. There are two ways of finding the mechanical advantage of a simple machine.

C. One way is to divide the resistance, or weight, by the effort that is exerted.

1. This expression can be stated as a formula:

$$\text{M.A.} = \frac{\text{Resistance}}{\text{Effort}}$$

2. If the effort is 2 pounds, and the resistance 8 pounds, the mechanical advantage is 8 ÷ 2, or 4.
3. This mechanical advantage is called the **actual mechanical advantage (A.M.A.)** because extra effort had to be exerted in overcoming friction, so this mechanical advantage is the advantage of force that you actually get when you use the machine.

D. The second way is to divide the distance the effort moves by the distance the resistance moves.

1. This expression can be stated as a formula, too:

$$\text{M.A.} = \frac{\text{Effort distance}}{\text{Resistance distance}}$$

2. If the effort moves 10 feet while the resistance moves 2 feet, the mechanical advantage is 10 ÷ 2, or 5.
3. This mechanical advantage is called the **ideal mechanical advantage (I.M.A.)**

because friction is not involved in this calculation.

4. For many of the simple machines there are also special, and usually easier, ways to find the ideal mechanical advantage (I.M.A.).

E. If extra effort were not needed to overcome friction, the actual mechanical advantage (A.M.A.) and ideal mechanical advantage (I.M.A.) would be exactly the same.

F. However, because extra effort is needed to overcome friction, the actual mechanical advantage (A.M.A.) is smaller than the ideal mechanical advantage (I.M.A.).

G. The ideal mechanical advantage (I.M.A.) then tells us the highest possible mechanical advantage we can get from a machine, whereas the actual mechanical advantage (A.M.A.) tells us the actual or real mechanical advantage we get when we use the machine.

H. A machine can also give us a mechanical advantage of speed.
1. When a machine makes an object move faster, we get a mechanical advantage of speed.
2. If the machine makes the object move five times as fast as the force that is acting on the machine, the mechanical advantage of speed is 5.

V. The Lever

A. A **lever** is a rigid bar, straight or curved, that rests on a fixed point called the **fulcrum.**

B. The force exerted on the lever is called the **effort.**

C. The force that the lever exerts, or the object that the lever lifts or moves, is called the **resistance.**

D. The distance from the fulcrum to the point where the effort is exerted is called the **effort arm.**

E. The distance from the fulcrum to the point where the resistance is exerted or lifted is called the **resistance arm.**

F. The closer the fulcrum is to the resistance, the less effort will be needed to move or lift the resistance, but the effort will move a longer distance, and the resistance will move a shorter distance.
1. There will be a gain in force, but a loss in distance and speed.
2. This action follows the principle of work.

G. The closer the fulcrum to the effort, the greater the force will be needed to move or lift the resistance, but now the effort will move a shorter distance, and the resistance will move a longer distance.
1. There will be a loss in force, but a gain in distance and speed.
2. This action also follows the principle of work.

H. The actual mechanical advantage (A.M.A.) of the lever can be found by dividing the resistance or weight by the effort.

I. The ideal mechanical advantage (I.M.A.) can be found in the following two ways:
1. Dividing the distance the effort moves by the distance the resistance moves.
2. Dividing the length of the effort arm by the length of the resistance arm.

J. Levers are divided into three classes, depending upon the positions of the effort, resistance, and fulcrum.

VI. First-Class Lever

A. A **first-class lever** is one in which the fulcrum is located anywhere between the effort (or force) and the resistance (or weight).

B. A first-class lever changes the direction of a force. The effort pushes in one direction while the resistance moves in the opposite direction.

C. When the fulcrum is closer to the resistance than to the effort, we gain in force, but get less speed and distance.

D. When the fulcrum is closer to the effort than to the resistance, we get more speed and distance, but lose in force.

E. When the fulcrum is exactly between the effort and the resistance, there is no change

in force, speed, or distance, but there is a change in direction.

F. Examples of first-class levers include the crowbar, scissors, pliers, tin snips, tack puller, and seesaw.

VII. Second-Class Lever

A. A **second-class lever** is one in which the resistance is between the effort and the fulcrum.

B. A second-class lever does not change the direction of a force. Both the effort and resistance move in the same direction.

C. In a second-class lever the fulcrum is usually closer to the resistance, so there is a gain in force.

D. Examples of second-class levers include the wheel barrow, nut cracker, crowbar, bottle opener, and oar of a rowboat.

VIII. Third-Class Lever

A. A **third-class lever** is one in which the effort is between the resistance and the fulcrum.

B. A third-class lever does not change the direction of the force.

C. In a third-class lever there is always a gain in speed and distance, and a loss in force.

D. Examples of third-class levers include the broom, shovel, sugar tongs, tweezers, and fishing pole.

IX. The Wheel-and-Axle

A. A simple **wheel-and-axle** machine is one where a large **wheel** is connected to a smaller wheel or shaft, called an **axle**.
  1. When either the wheel or the axle turns, the other part also turns.
  2. One complete turn of the wheel produces one complete turn of the axle.
  3. If the wheel turns but the axle does not, it is not a wheel-and-axle machine.

B. The wheel does not have to be a complete wheel.
  1. Instead there may be a crank that turns.
  2. When the crank is turned, it makes a complete circle, just as though it were a complete wheel.

C. A wheel-and-axle is really a form of the lever. It is a spinning lever.
  1. This spinning lever can be seen very clearly when a crank is used instead of a wheel.
  2. The fulcrum is at the center of the axle and the wheel or crank.
  3. The radius of the wheel is the effort arm, and the radius of the axle the resistance arm, of the lever.

D. A wheel-and-axle can change the direction of a force.

E. When the wheel turns the axle, there is a gain in force.
  1. A smaller force, or effort, at the wheel will move a larger weight, or resistance, at the axle.
  2. But the weight, or resistance, will not move as far or as fast as the force, or effort, because the wheel is larger than the axle.
  3. The larger the wheel, as compared to the axle, the greater the gain in force will be.

F. When the axle turns the wheel, there is a loss in force and a gain in distance and speed.
  1. A larger force must be exerted at the axle, but the resistance at the wheel will turn faster and farther.
  2. The smaller the axle, as compared to the wheel, the greater the gain in speed and distance.

G. The actual mechanical advantage (A.M.A.) of the wheel-and-axle can be found by dividing the weight or resistance lifted by the effort exerted.

H. The ideal mechanical advantage (I.M.A.) can be found in the following ways:
  1. Dividing the distance the effort moves by the distance the weight or resistance moves.
  2. Dividing the circumference of the wheel by the circumference of the axle.

3. Dividing the diameter of the wheel by the diameter of the axle.
4. Dividing the radius of the wheel by the radius of the axle.

I. Examples of wheel-and-axle machines containing complete wheels include the automobile steering wheel, gear wheels of the bicycle, door knob, and screw driver.

J. Examples of wheel-and-axle machines containing a crank instead of a complete wheel can be found in the pencil sharpener, meat grinder, and egg beater.

X. The Pulley

A. A **pulley** is a wheel that turns around an axle.
1. Usually there is a groove in the rim of the pulley so that the rope around the pulley will not slip off.
2. Sometimes two or more pulleys are placed side by side on the same axle.

B. There are two types of pulleys: the **fixed pulley** and the **movable pulley.**

C. The fixed pulley does not move. It is fastened to one spot.
1. It helps us only by changing the direction of the force.
2. It gives no gain in force, speed, or distance.
3. Fixed pulleys are used with flag poles, clothes lines, and Venetian blinds.
4. The fixed pulley acts like a turning first-class lever, with the fulcrum at the center of the axle, the effort at one rim of the pulley wheel, and the resistance at the other rim.

D. The movable pulley moves along the rope.
1. It helps us gain in force, but we lose in distance.
2. In a single movable pulley two sections of the rope support the pulley so that only half as much effort is needed to raise a resistance.
3. However, the effort must now move about twice as far as the resistance.
4. A movable pulley does not change the direction of the force.
5. A movable pulley acts like a turning second-class lever, with the fulcrum at one rim of the pulley wheel, the resistance at the center of the axle, and the effort at the other rim of the pulley wheel.

E. A single pulley may be combined with a movable pulley to change direction and gain force at the same time.
1. Such a combination is called a **block and tackle.**
2. Several fixed and movable pulleys can be used in a block and tackle.
3. Each fixed pulley changes the direction of the force, and each movable pulley changes the amount of the force.
4. The more movable pulleys used, the less force will be needed.
5. A block and tackle is used in scaffolds for painters and for billboard postermen.

F. The actual mechanical advantage (A.M.A.) of a pulley, or set of pulleys, can be found by dividing the resistance by the effort.

G. The ideal mechanical advantage (I.M.A.) can be found in the following ways:
1. Dividing the distance the effort moves by the distance the resistance moves.
2. Counting the number of sections of rope that support the movable pulleys.

XI. The Inclined Plane

A. An **inclined plane** is a slanting surface that connects one level to a higher level.

B. An inclined plane is a simple machine that gives us a gain in force.
1. By moving an object up an inclined plane we use less force in getting the object up to the higher level than if we had to lift the object directly from the lower to the higher level.
2. We gain in force at the expense of distance. Now the object must be moved a longer distance as it travels up the inclined plane to reach the desired higher level.

C. The longer the inclined plane, the more gradual the slope becomes, and the less

force will be needed to move the body up the incline.

D. The shorter the inclined plane, the steeper the slope becomes, and the more force will be needed to move the body up the inclined plane.

E. The actual mechanical advantage (A.M.A.) of an inclined plane can be found by dividing the resistance by the effort.

F. The ideal mechanical advantage (I.M.A.) can be found by dividing the length of the inclined plane by the height.

G. Examples of the inclined plane include a plank, ramp, sloping floor of a theater or auditorium, straight road up a hill, and a stairway.

XII. The Wedge

A. A wedge is a simple machine that is used either to spread an object apart or to raise an object.

B. A wedge has a sloping or slanting side just like an inclined plane.

C. A single wedge looks just like an inclined plane, and has one sloping side.

D. A double wedge looks like two inclined planes that have been joined together with their sloping sides facing outward.

E. A wedge is a form of inclined plane with only one difference.
   1. With the inclined plane the object moves up the incline.
   2. With the wedge the incline moves into or under the object.

F. The wedge not only gives us a gain in force, but it also changes the direction of the force.
   1. The longer or thinner the wedge, the greater the gain in force.
   2. The gain in force is obtained at the expense of distance because the effort moves over a longer distance than the resistance.
   3. The farthest the resistance can be moved is the thickness of the big end of the wedge.

G. The actual mechanical advantage (A.M.A.) of a wedge can be found by dividing the resistance by the effort.

H. The ideal mechanical advantage (I.M.A.) can be found by dividing the length of the wedge by the thickness of the big end.

I. The actual mechanical advantage of a wedge is always much less than the ideal mechanical advantage because there is much friction between the wedge and the object.

J. Friction is helpful in this case because it keeps the wedge from slipping out.

K. Examples of the wedge include the ax, knife blade, scissors blade, chisel, pin, nail, and plow.

XIII. The Screw

A. The screw is an inclined plane that winds around and around in a spiral.

B. The spiral ridge of the screw is called the **thread**.

C. One complete turn of the screw moves the screw into the object the distance from one thread to another.

D. The distance between two threads is called the **pitch** of the screw.

E. The screw gives us a gain in force, but at the expense of distance.
   1. The effort distance of one complete turn of the screw is larger than the resistance distance of one pitch.
   2. The closer the threads are together, the smaller the pitch becomes, and the greater the gain in force we get.

F. The actual mechanical advantage (A.M.A.) of the screw can be found by dividing the resistance by the effort.

G. The ideal mechanical advantage (I.M.A.) can be found by dividing the circumference of the screw (distance of one complete turn) by the pitch.

H. Because of friction the actual mechanical advantage is very much less than the ideal mechanical advantage.
   1. However, friction helps keep the screw from turning backward or pulling out.
   2. We can make up for the loss of force

caused by friction by using another machine, like the lever or wheel and axle, to turn the head of the screw.

3. Using another machine to turn the head of the screw gives us a very large gain in force.

I. Examples of the screw are found in the wood screw, bolt, caps of jars and bottles, base of the electric light bulb, monkey wrench, clamp, vise, and piano stool.

XIV. Efficiency of Machines

A. There are two ways of finding out how efficient a machine is.

B. One way is to divide the actual mechanical advantage by the ideal mechanical advantage, and then multiplying by 100.

1. This can be stated as a formula:

$$\text{Efficiency} = \frac{\text{A.M.A.}}{\text{I.M.A.}} \times 100$$

2. We multiply by 100 so that we can describe the efficiency of a machine in percentages.

3. If the A.M.A. of a machine is 4, and its I.M.A. is 5, the efficiency of the machine is $(4 \div 5) \times 100$, or 80 percent.

C. The second way to find the efficiency is to divide the amount of work put out by the machine by the amount of work put into the machine, and then multiply by 100.

1. This can be stated as a formula:

$$\text{Efficiency} = \frac{\text{Work put out}}{\text{Work put in}} \times 100$$

2. The work put out can be found by multiplying the resistance by the distance the resistance moves, and the work put in can be found by multiplying the effort by the distance the effort moves.

3. If a machine puts out 30 foot-pounds of work while the work put into the machine is 50 foot-pounds, the efficiency of the machine is $(30 \div 50) \times 100$, or 60 percent.

D. Because extra force, or effort, is needed to overcome friction, the actual mechanical advantage is always less than the ideal mechanical advantage, and the work put out is always less than the work put in, so the efficiency of a machine is always less than 100 percent.

1. In some levers the friction is so small that the efficiency may be nearly 100 percent.

2. The wheel-and-axle can have an efficiency as high as 70 percent.

3. The efficiency of a combination of pulleys, or block and tackle, is usually 60 percent or less.

4. If the surface of an inclined plane is very smooth and hard, the efficiency of the inclined plane may be as high as 80 percent.

5. The friction of the wedge is so great that it is almost impossible to calculate its efficiency.

6. The screw has a very high mechanical advantage, but the friction is so great that the screw's efficiency is usually no more than 25 percent.

XV. Compound Machines

A. Most of the machines we use in daily life are made up of two or more simple machines.

B. A machine that is a combination of two or more simple machines is called a **compound machine.**

C. There are many examples of compound machines around us.

1. The handle of an ax is a lever, and the blade is a wedge.

2. A scissors has two levers with blades that are wedges.

3. The handle of a pencil sharpener is part of a wheel-and-axle that turns two screws with sharp wedge-shaped edges that act like blades to sharpen the pencil.

4. The meat grinder is just like the pencil sharpener except that it has just one screw with wedge-shaped edges that act like blades.

5. A rotary can opener is made up of a wheel-and-axle and a circular wedge.

XVI. Gears

A. Sometimes, in compound machines, one wheel is used to turn another wheel.

B. Each wheel is connected to an axle that also turns, making a wheel-and-axle machine.

C. One way of making a wheel turn another wheel is by putting a tight belt around both wheels.
   1. When one wheel is turned, it makes the belt move and turn the other wheel.
   2. The second wheel moves in the same direction as the first wheel.
   3. If we want the second wheel to turn in the opposite direction to the first wheel, we cross the belt that goes around both wheels.
   4. When the first wheel, the **driving wheel,** is larger than the second wheel, the **driven wheel,** we get a gain in speed, but we lose in force.
   5. When the driving wheel is smaller than the driven wheel, we get a gain in force and a loss in speed.

D. A second way to make wheels turn is to put teeth on the wheels and slip a chain around both wheels.
   1. The teeth fit into the open places in the chain, and the cross-pieces of the chain fit into the notches between the teeth.
   2. The teeth and notches of the wheels stop the chain from slipping.
   3. Wheels with teeth and notches in them are called **gears** or **gear wheels.**

E. The bicycle is a machine that uses gears and a chain.
   1. The gears are part of a wheel-and-axle machine.
   2. The pedal turns a crank that turns a large gear.
   3. A chain connected from the large gear to the smaller gear on the rear wheel turns the smaller gear.
   4. The smaller gear then turns the rear wheel, which drives the bicycle forward.
   5. Each time the pedals turn the larger gear around once, the smaller gear turns the rear wheel around many times.
   6. In this way the gears of a bicycle give up force but gain in speed and distance.

F. A third way to make wheels turn is to fit two gears together without a chain.
   1. The teeth of one gear fit into the notches of the second gear and make the second gear turn.
   2. Each gear is part of a wheel and axle.
   3. When one gear makes another gear move this way, the second gear moves in a direction opposite to the first gear.
   4. If a large gear turns a small gear, there is a gain in speed and distance and a loss in force.
   5. If a small gear turns a larger gear, there is a gain in force but a loss in speed and distance.
   6. To get two gears to move in the same direction, a third gear must be placed between them.

G. The actual mechanical advantage of two gears may be found in the following ways:
   1. Comparing the forces that both gears exert.
   2. Comparing the speeds of both gears.

H. The ideal mechanical advantage can be found by comparing the number of teeth that each gear has.

XVII. Engines

A. Although man had invented machines that multiplied the amount of force he could exert, he still had to supply the force needed to run the machines.
   1. At first man used the force of his muscles or the muscles of strong animals like the horse and the ox.
   2. Then man learned to use other more powerful forces, such as the movement of the wind, falling or moving water, and heat or gases produced from burning fuels.
   3. He invented devices and engines that

used these powerful forces to run his machines.

4. As these devices and engines became more improved and efficient, they were able to run larger and more complicated machines.

B. The **windmill** is a device for using the movement of the wind to run a machine and do work.

1. The windmill has blades, or propellers, connected to a shaft that runs through the center of the blades.
2. The blades are set at an angle and slope backward so that, when the wind hits the blades, it makes the blades turn around and around.
3. The turning blades make the shaft turn so that together they act like a wheel-and-axle machine.
4. The windmill can be used to pump water, grind grain, or run an electric generator to produce electricity.
5. The windmill runs only as long as the wind blows hard enough to turn the blades, so it works best in places where the wind blows much or most of the time.

C. The **water wheel** is a device that uses the force of falling or moving water to run machines.

1. It has many blades, which make the wheel turn quickly when the water strikes them.
2. A shaft in the center of the wheel turns as the wheel turns, forming a wheel-and-axle machine.
3. The first water wheels made use of the force of natural falling or moving water, and were used to grind grain or run machines in factories located beside rivers or waterfalls.
4. Today special water wheels, called **turbines**, use the tremendous force of falling or moving water from huge dams, such as the Grand Coulee Dam on the Columbia River or the Norris Dam on the Tennessee River.
5. Water turbines are used to run giant electric generators, which produce large amounts of electricity.

D. The **steam engine** uses the heat of burning fuels, such as coal, gas, and oil, to run machines.

1. The heat of the burning fuel changes water into steam.
2. When water changes into steam, it expands about 1700 times, and the expanding steam provides the energy to operate the engine.
3. The steam engine is called an **external combustion machine** because the fuel is burned outside the engine.
4. The steam is produced by making water boil in a boiler outside the engine.
5. The steam then passes through a pipe into a cylinder inside the engine.
6. In the cylinder the expanding steam pushes a sliding piston back and forth.
7. The piston is attached to a wheel with a lever called a **connecting rod.**
8. As the piston moves back and forth in the cylinder, the attached connecting rod makes the wheel turn.
9. Every movement of the piston is useful, producing power that makes the wheel turn.
10. The steam engine has been used to pull trains, push boats, saw wood, spin thread, and weave cloth.

E. The **steam turbine** also uses steam to run machines.

1. It is more powerful and runs more smoothly than the steam engine.
2. It works very much like the water turbine except that it is run by steam that comes from a boiler.
3. Most steam turbines have many curved blades arranged in rows so that a row of movable blades is followed by a row of fixed blades.
4. The expanding steam is shot through nozzles at a slant or angle against the movable blades, making the blades spin at a very high speed.
5. After the steam has passed a row of movable blades, it is then directed by a

row of fixed blades to the next row of movable blades.

6. Each row of movable blades is larger than the row before it because the steam expands as it travels through the turbine and can make good use of the larger space to get more power from the turbine.
7. The spinning movable blades turn a long rod that can run a large electric generator or turn the propellers of a big ship.

F. The **gasoline engine** uses the hot, expanding gases formed by burning gasoline to run machines.

1. It is called an **internal combustion engine** because the fuel is burned inside the cylinder of the engine.
2. Outside the engine a device called the **carburetor** changes the gasoline liquid into gasoline vapor and mixes this vapor with the right amount of air to make the gasoline burn properly.
3. Fitted into the top or head of the cylinder is a **spark plug**, which has a small space or gap between its two metal tips so that at the right moment a hot electric spark can jump across the gap and make the mixture of gasoline vapor and air in the cylinder burn.
4. A piston in the cylinder moves up and down when the gasoline engine is running.
5. In the most common gasoline engine, used by automobiles, the piston has to move four times, or make four strokes, inside the cylinder to get just one stroke that will produce power to run the machine.
6. In the first stroke or movement, called the **intake stroke**, the piston moves down, allowing a valve at the top of the cylinder to open and let the mixture of gasoline vapor and air enter the cylinder.
7. Then the piston moves up for its second stroke, called the **compression stroke**, compressing or squeezing the mixture of gasoline and air into a very small space.
8. Just when the mixture of gasoline and air is compressed the right amount, an electric spark from the spark plug sets the mixture on fire.
9. The mixture burns quickly, almost explosively, and produces very hot, expanding gases, which give the piston a tremendous downward push.
10. This third downward stroke is called the **power stroke**, and provides the power that runs the machine.
11. The piston then moves up again for its fourth stroke, called the **exhaust stroke**, pushing out the waste gases through another valve at the top of the cylinder.
12. Now the same series, or cycle, of four strokes starts all over again, and continues in this way as long as the engine is running.
13. The piston is attached to a **connecting rod**, which turns the **crankshaft** of the engine.
14. The crankshaft is connected to the **driveshaft**, which is then connected to the axle of a machine, like the automobile, and makes the machine run.
15. Because only one piston stroke in every four strokes is a power stroke, the more cylinders a gasoline engine has, the more smoothly it will run.
16. An automobile has at least four cylinders in its engine so that there will be one power stroke taking place all the time.
17. Compact automobiles usually have four-cylinder gasoline engines, but larger automobiles usually have six-cylinder or eight-cylinder engines.
18. Gasoline engines are also used to run small airplanes, motorcycles, motorbikes, outboard motors, lawn mowers, and power saws.

G. The **Diesel engine** also uses hot, expanding gases to run machines.

1. Machines that use Diesel engines do not use a carburetor or spark plugs.
2. They use a special fuel oil that is much cheaper than gasoline.

3. The most common Diesel engine uses a cycle of only two strokes to produce one power stroke.
4. The first stroke is a combination intake-compression-exhaust stroke.
5. During the first stroke, air is blown in at one side of the cylinder while waste gases are being forced out through two valves at the top of the cylinder.
6. Then the piston moves up, compressing the air very much more than in the cylinder of a gasoline engine, making the air very hot.
7. When the piston nears the top of the cylinder, the fuel oil is sprayed into the cylinder through a nozzle at the top, and the hot air makes the oil catch fire immediately and burn very quickly.
8. The hot, expanding gases push the piston down with great force for its second, or power, stroke.
9. When the piston nears the bottom of the cylinder, the waste gases are pushed out through the valves and more air enters the cylinder.
10. Because great pressure is produced in the cylinders, they must be made of thick metal, and the resulting weight makes it impractical to use Diesel engines in small machines and in automobiles.
11. Because the Diesel engine is so much more powerful and efficient than the gasoline engine, it is very commonly used to drive all kinds of trucks, buses, tractors, power shovels or bulldozers, locomotives, ships, submarines, and electric generators.

H. Man has also developed the electric motor (discussed in Chapter 21, "Magnetism and Electricity"), which uses electricity to run machines and do work.

LEARNING ACTIVITIES FOR "FRICTION AND MACHINES"

FRICTION

1. *Uneven surfaces cause friction* · Obtain two pieces of wood with rough surfaces and rub them together. Note the friction produced. Examine the surfaces under a magnifying glass and note the bumps and hollows. Make a large-scale model of these bumps and hollows from a block of balsa wood about 6 inches long, 3 inches wide, and 1½ inches thick. Use a coping saw or a jigsaw to cut out giant-sized bumps and hollows (Figure 17–1). Rub the two pieces of balsa wood together, reversing the position of one of the pieces, and see how the bumps and hollows catch and stick.

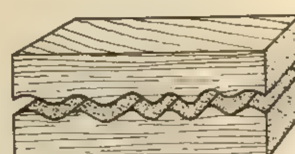


FIGURE 17–1.
BUMPS AND HOLLOWS CAUSE FRICTION.

2. *Friction produces heat* · Have the children rub the palms of their hands together briskly and note the heat produced by the resulting friction. Point out that the more briskly the hands are rubbed, the greater the friction, and the hotter the hands become.

3. *The nature of the materials affects friction* · Rub two pieces of wood with smooth surfaces together. Then rub two pieces of soft,

white bread together. Note that firm, hard materials produce less friction than soft, clinging materials.

4. *The nature of the surfaces affects friction* · Rub a piece of absorbent cotton first across the surface of some coarse sandpaper, and then across the surface of a pocket mirror. Bits of cotton will catch and stick on the rough sandpaper, but not on the mirror.

5. *The amount of area between surfaces affects friction* · Obtain a rectangular block of wood and put a screw eye into one end of the block. Place the block of wood, wide surface down, on a table and put a book on top of the block (Figure 17–2). Use a string to connect the screw eye to a spring balance. While holding the balance horizontally, pull the block of wood across the table and note how much force is needed to accomplish this. Repeat the experiment, using the narrower surface of the wooden block this time, and compare the forces. (A strong rubber band can be used instead of the spring balance, but the results will now be qualitative rather than quantitative.)

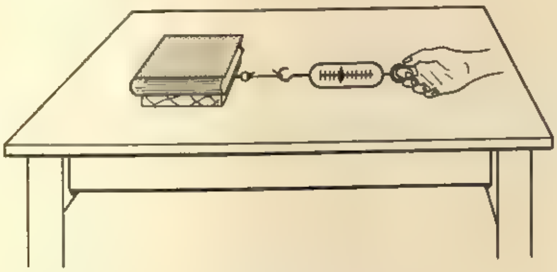


FIGURE 17–2.
THE GREATER THE AREA BETWEEN TWO SURFACES, THE MORE FRICTION WILL BE PRODUCED.

6. *The pressure of the surfaces against each other affects friction* · Repeat Learning Activity 5 above, using first one book and then three books on top of the wooden block. Note how the increase in pressure causes the friction between surfaces to become greater.

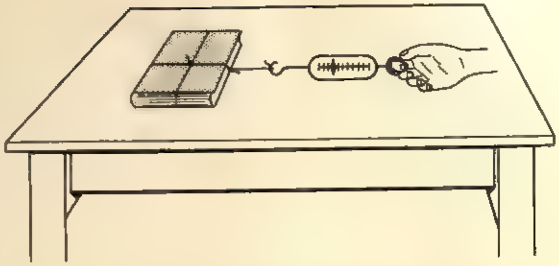


FIGURE 17–3.
SLIDING FRICTION IS LESS THAN STARTING FRICTION.

7. *Sliding friction is less than starting friction* · Tie some string around a large, thick book and place the book on the table. Attach the string to a spring balance (Figure 17–3). Pull on the scale (making sure to hold it horizontally) until the book begins to move. Note the reading on the scale just before the book moves. Now pull the scale and book together along the table and note the reading on the scale while the book is moving.

8. *Rolling friction is less than sliding friction* · Tie a string around a large, thick book and attach the string to a spring balance, as described in Learning Activity 7 above. Pull the scale and book together along the table and note the reading on the scale while the book is moving. Now place about a dozen round pencils underneath and beside the book, and pull the book along the table again (Figure 17–4). Note the difference in the reading of the scale as the book moves along the rollers.

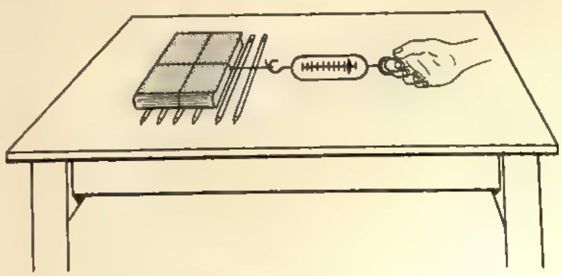


FIGURE 17–4.
ROLLERS WILL REDUCE FRICTION.

9. *Making the surfaces smoother reduces friction* · Obtain two pieces of wood with rough surfaces on both sides. Sand one side of each piece of wood until the surface is quite smooth. Now rub the rough surfaces of both pieces of wood together and note the amount of friction. Rub the smooth surfaces together and note the reduction in friction.

10. *Lubricants reduce friction* · Obtain two pieces of dry toast and rub them together. Note the amount of friction and also the wearing away of bits of toast. Now spread some jam thickly across each piece of toast and rub the pieces together again. The pieces will now slide smoothly over each other because the jam filled the hollows and covered the bumps, reducing the friction.

Have the children look for and make a list of examples of reducing friction with such lubricants as oil, grease, wax, soap, and graphite.

11. *Rollers reduce friction* · Repeat Learning Activity 8 above, showing that rolling friction is less than sliding friction.

12. *Wheels reduce friction* · Obtain a large cardboard carton about the same size as the body of a child's play wagon or cart. Place one child in the carton and have another child push the carton across the floor. Now have the child in the carton climb into a play wagon and have the second child push the wagon across the floor. Note the amount of force required to push the carton and the wagon.

13. *Ball bearings reduce friction* · Obtain the metal screw cap from a large glass jar and place it, lip down, on the table. Put a heavy book on the metal screw cap and try to spin the book. The book will spin once or twice and then stop because of friction. Take away the book and place some marbles under the screw cap (Figure 17–5). Make sure you use large enough marbles so that the lip of the screw cap does not touch the table. Now put the book back on the screw cap and try spinning the book again. The book spins easily, with the marbles acting as ball bearings to reduce the friction.

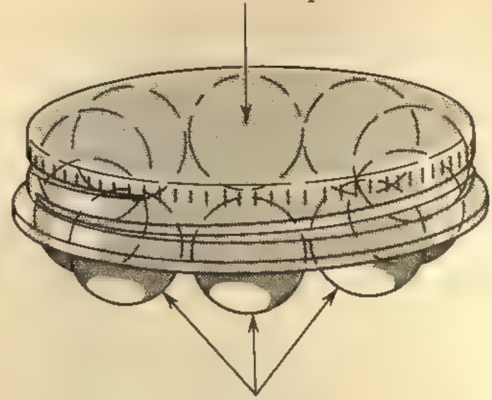


FIGURE 17–5.
BALL BEARINGS WILL REDUCE FRICTION.

14. *Useful and harmful effects of friction* · Draw two columns on the chalkboard. In one column have the children make a list of harmful effects of friction. In the second column let them list the useful effects of friction. Ask the children to describe some of the unusual situations that would happen if there were no friction on earth.

MACHINES

1. *All machines transfer a force* · Operate a variety of hand tools and kitchen appliances. In each case show how a force is exerted on the machine at one place, and then how the machine transfers this force to another place where the work is done.

2. *Machines can increase the amount of a force* · Drive about three fourths of a nail into a board. Have the children try pulling the nail out of the board with their hands. Now let one of the children use a claw hammer to pull out the nail. Point out that the hammer changes a small force at the handle into a large force at the claws.

3. *Machines can change the direction of a force* · Have the children observe the pulley at the top of the school flagpole. The pulley changes the direction of a force because pulling down on one side of the rope slung over the pulley makes the flag fastened to the other side of the rope go up.

4. *Machines can increase the distance and speed of a force* · Let one of the children sweep with a kitchen broom. As the child sweeps, point out that the upper part of the broom handle is moving just a short distance back and forth. However, the lower and bottom part of the broom are moving faster and farther.

5. *Machines cannot increase both force and distance at the same time* · Repeat Learning Activities 2 and 4 above. When using the hammer, point out that, although there was an increase in force at the claws, the claws now moved a smaller distance than the handle. With the broom, the bottom part increased in speed and distance, but the force exerted at the bottom part was much less than the force being exerted on the upper part of the broom handle. As a result, the gain in speed and distance was accompanied by a loss in force.

6. *Work* · Have one of the children try to pull open a bolted door. Point out that, although the child exerted a force, according to scientists he did not do any work because the force did not move through a distance. Let the children lift weighed objects to measured heights and calculate the number of foot-pounds of work done. Also, have the children pull objects with a spring balance across a surface, and then calculate the amount of work done.

7. *First-class lever* · Make your own lever from a piece of wood 36 inches long, 2 to 3 inches wide, and about ½ inch thick. Use a triangular block of wood 2 inches wide and 1 inch high as a fulcrum. To make it easier for the lever to rest or to pivot on the fulcrum, cut grooves on the underside of the wood board at each end and at the 9-, 18-, and 27-inch marks. Now rest the center of the board (at the 18-inch mark) on the fulcrum. Place a weight or brick at one end of the board and push down at the other end (Figure 17–6).

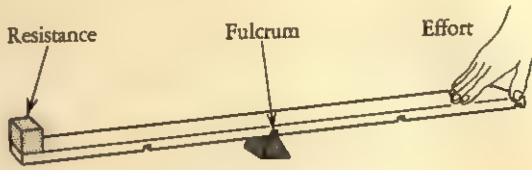


FIGURE 17–6.
A FIRST-CLASS LEVER.

Note the force you have to exert to lift the weight. Also, note that you push down while the weight moves up so that there is a change in direction, and your hand moves just as far down as the weight moves up.

Move the fulcrum nearer the weight and push down on the board again. This time less force will be needed to lift the weight, but now the weight moves up a little, while your hand moves down a lot. Now move the fulcrum so that it is near your hand. You will have to use a lot of force to lift the weight, but the weight will now move up a lot while your hand moves down just a little.

You may want to repeat this activity, this time using quantitative techniques. If so, insert a screw eye into one end of the board and have this end extend a little beyond the edge of the table (Figure 17–7). For the resistance use a known weight or a brick whose weight you have determined. Attach a spring balance to the screw eye to measure the effort needed to lift the weight. Now place the fulcrum at different positions under the board and measure the force necessary to lift the weight in each case.

Measure the length of the effort arm and the resistance arm. Also measure the distances that both the resistance and the effort move. Find the ideal and the actual mechanical advantage. Calculate the amount of work done, both input

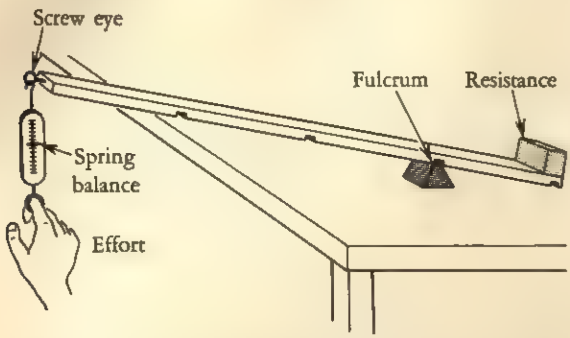


FIGURE 17–7.
LESS EFFORT IS NEEDED WHEN THE FULCRUM IS NEARER THE RESISTANCE.

and output, and determine the efficiency of the lever. Keep in mind that you will obtain only approximate results because the weight of the board will not have been taken into consideration in the calculations. Also, when the spring balance is held upside down, this position affects the reading of the balance.

Have the children locate and identify other examples of first-class levers. Let them repeat this learning activity, using some of these examples.

8. *Second-class lever* · Repeat Learning Activity 7 above, but this time position the board so that it is a second-class lever, with the fulcrum between the effort and the fulcrum (Figure 17–8). Conduct both qualitative and quantitative measurements. Note that the second-class lever does not change the direction of the force because both the effort and the resistance move upward.

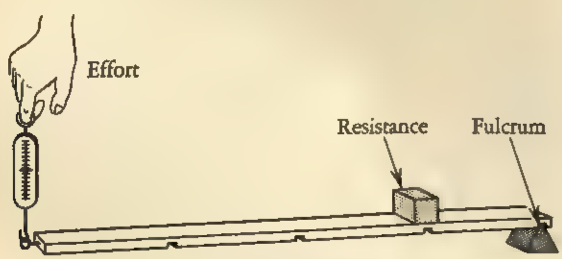


FIGURE 17–8.
A SECOND-CLASS LEVER.

Have the children locate and identify other examples of second-class levers. Let them repeat this learning activity, using some of these examples.

9. *Third-class lever* · Repeat Learning Activity 7 above, this time positioning the board so that it is a third-class lever, with the effort between the resistance and the fulcrum (Figure 17–9). You will have to insert a second

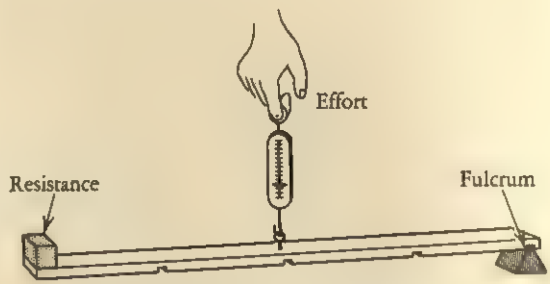


FIGURE 17–9.
A THIRD-CLASS LEVER.

screw eye into the board, this time into the top surface. Also, you will have to press down on the board just above the fulcrum to prevent the board from being lifted up into the air when you pull up on the spring balance. Conduct both qualitative and quantitative measurements. Note that the third-class lever does not change the direction of the force because both the effort and the resistance move upward.

Have the children locate and identify other examples of third-class levers. Let them repeat this learning activity, using some of these examples.

10. *Wheel-and-axle* · Obtain a pencil sharpener and remove the cover. Clamp the pencil sharpener to the edge of a table, as shown in Figure 17–10. Turn the handle of the sharpener and point out that when the handle is turned, it makes a complete circle, just as though it were a complete wheel. The shaft of the sharpener is the axle. When the handle

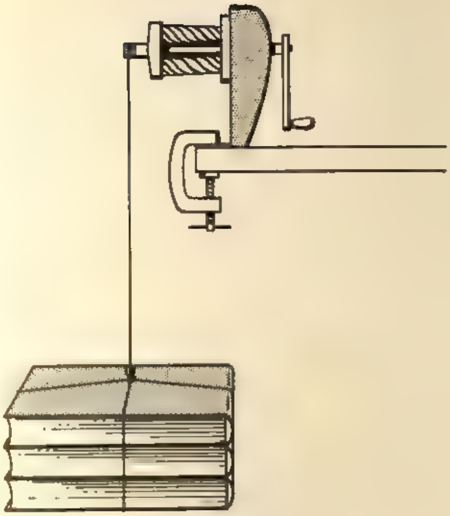


FIGURE 17–10.
THE PENCIL SHARPENER ACTS AS A WHEEL-AND-AXLE.

Draw a diagram to show that the wheel-and-axle is a form of spinning first-class lever (Figure 17–11). Its fulcrum is always at the

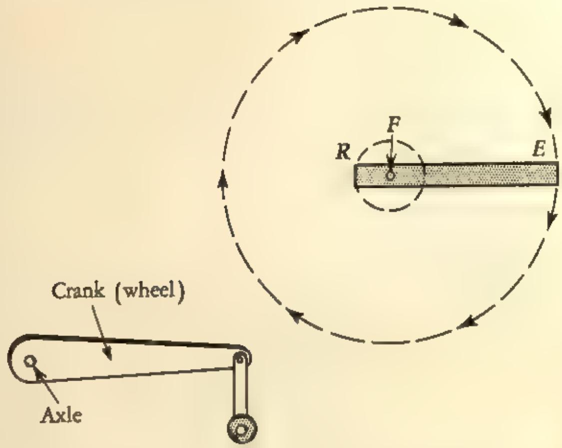


FIGURE 17–11.
THE WHEEL-AND-AXLE IS A SPINNING FIRST-CLASS LEVER.

(wheel) is turned, the shaft (axle) is turned.

Tie three books together with a string and have the children lift the books with the string, noting the force needed to do this lifting. Tie the other end of the string firmly around the shaft of the pencil sharpener, using cellophane tape if necessary, to keep the string from slipping. Now turn the handle of the sharpener and lift the books.

Note that much less force is needed to turn the handle than to lift the books directly. Point out that this gain in force is accompanied by a loss in distance and speed because the handle must move many times to raise the books a short distance. Find the ideal mechanical advantage of the pencil sharpener as a wheel-and-axle machine. (The radius of the wheel is the length of the handle, and the radius of the axle is one half of the diameter of the shaft.)

Turn the handle of the pencil sharpener until the books are close to the shaft, and then let go of the handle and allow the books to move down. Now the axle is turning the wheel. Note the loss in force, but the large gain in distance and speed as the handle spins rapidly.

center of the axle and the wheel. The radius of the wheel and the radius of the axle are the two arms of the lever. Have the children locate and identify other examples of wheel-and-axle machines. Let them repeat the experiment described above, using some of these examples.

11. *Fixed pulley* · Obtain a piece of wood about 36 inches long, 3 inches wide, and ½ inch thick. Screw two cup hooks about 4 inches apart into the board, and place the board on the backs of two chairs placed a short distance apart (Figure 17–12). Tie a string around a brick or book and weigh it with a spring balance. Attach a pulley to one cup hook and pass a string around the groove of the pulley. Connect one end of the string to the brick and the other end to a spring balance.

Pull down on the spring balance. Note that the force needed to raise the brick is just about equal to the weight of the brick, so all you have done is to change the direction of your force. Calculate the amount of work done, both input and output. Find the mechanical

advantage and determine the efficiency of the fixed pulley.

Draw a diagram to show that the fixed pulley is a form of spinning first-class lever (Figure 17–13). Its fulcrum is at the center of the axle, with the effort and resistance at opposite ends of the wheel. Note that the effort arm and the resistance arm are equal.

12. *Movable pulley* · Rearrange the pulley and brick as shown in the diagram (Figure 17–14). Pull up on the spring balance and note

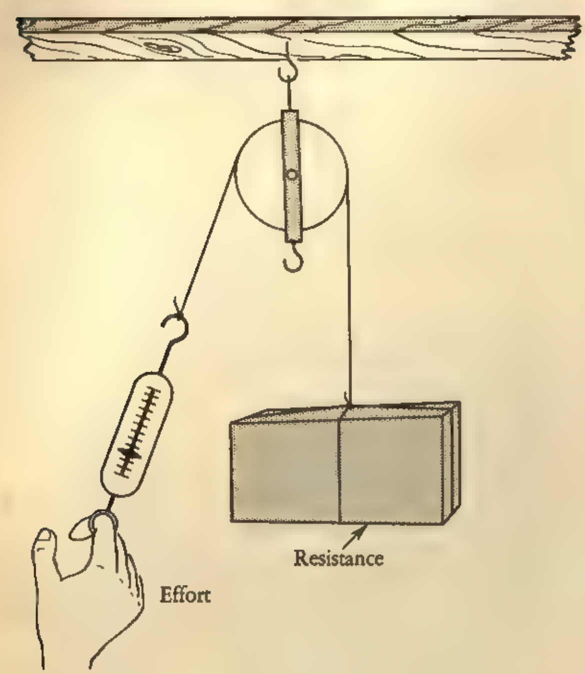


FIGURE 17–12.
A FIXED PULLEY CHANGES DIRECTION.

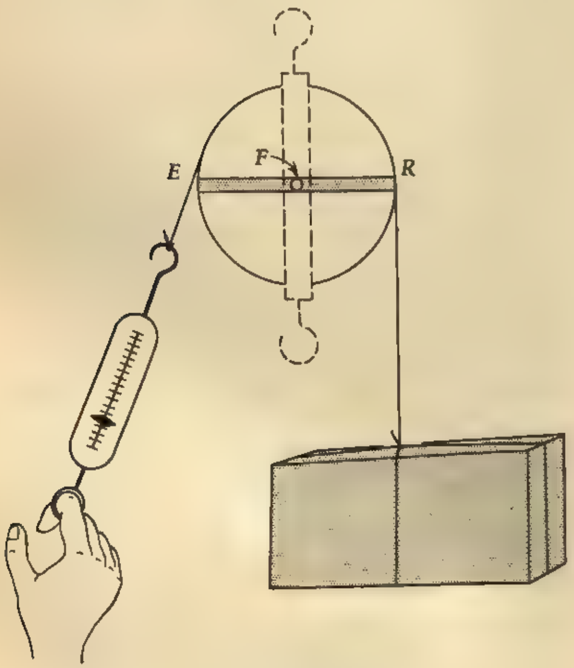


FIGURE 17–13.
A FIXED PULLEY IS A SPINNING FIRST-CLASS LEVER.

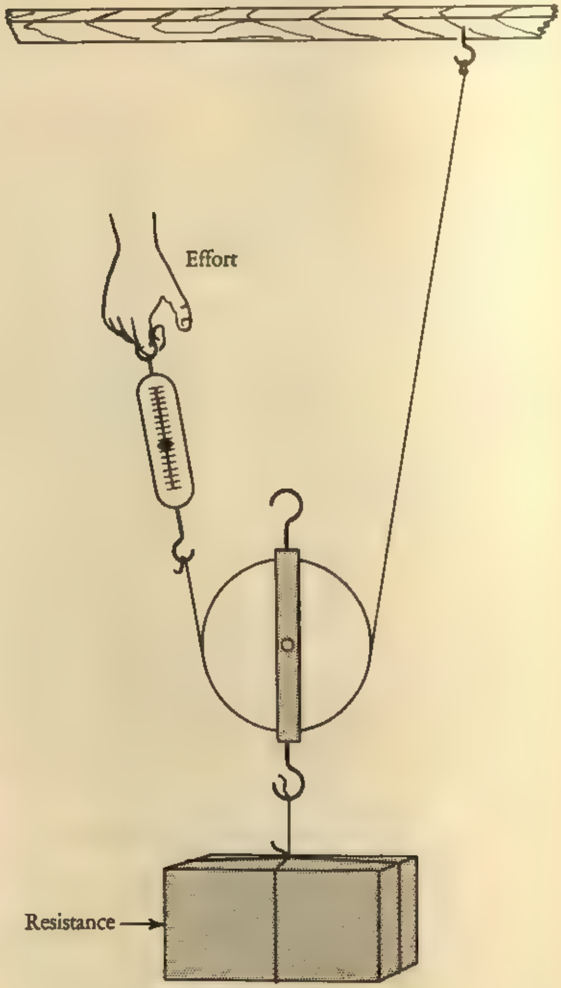


FIGURE 17–14.
A MOVABLE PULLEY REQUIRES HALF AS MUCH FORCE AS A FIXED PULLEY.

that only half the force is needed as with the fixed pulley. However, your effort must move twice as far as the distance the brick was lifted. Note that there is now no change in the direction of your force. Calculate the amount of work done, both input and output. Find the ideal and actual mechanical advantage, and determine the efficiency of the movable pulley.

Draw a diagram to show that the movable pulley is a form of spinning second-class lever

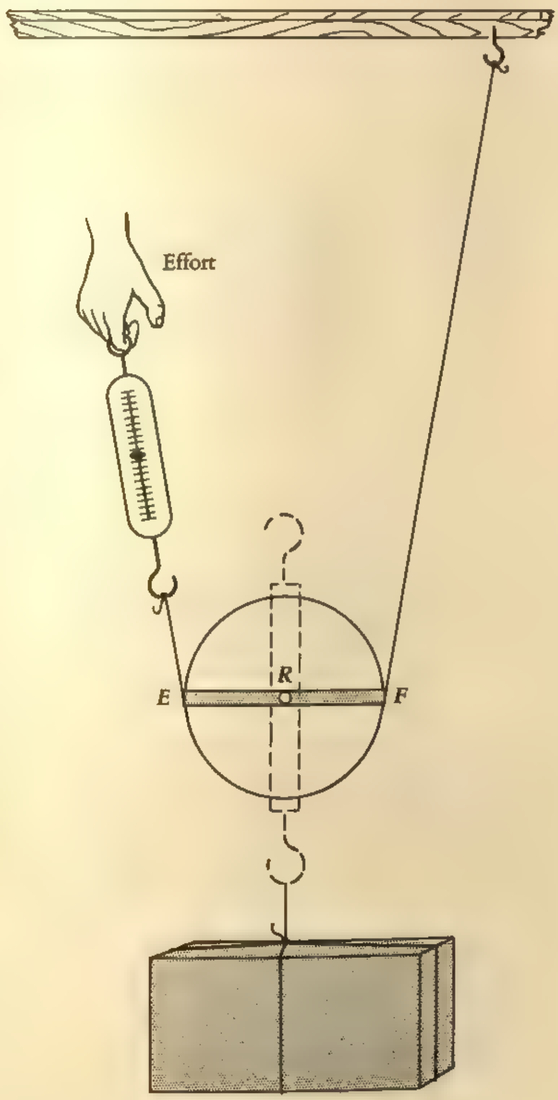


FIGURE 17–15.
A MOVABLE PULLEY IS A SPINNING SECOND-CLASS LEVER.

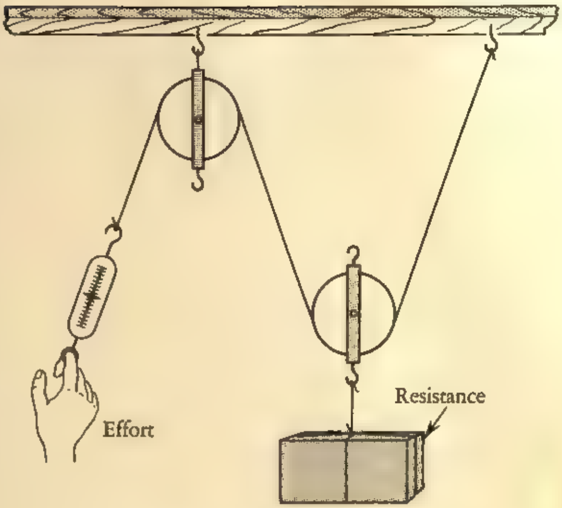


FIGURE 17–16.
A BLOCK AND TACKLE IS A COMBINATION OF A FIXED AND A MOVABLE PULLEY.

(Figure 17–15). Its fulcrum is at one end of the wheel, the effort at the opposite end, and the resistance at the center of the axle. The effort arm is twice as long as the resistance arm.

13. *Block and tackle* · Use two pulleys to form a combination of a fixed and a movable pulley, as shown in the diagram (Figure 17–16). Note that there is no difference between this block and tackle and the movable pulley in Learning Activity 12 above as to increase in force, work done, mechanical advantage, and efficiency. The block and tackle gives you increasing force and changing direction at the same time. If possible, repeat, using a double fixed and a double movable pulley.

14. *Inclined plane* · Obtain a board about 3 feet long, 6 inches wide, and ½ inch thick. Rest one end of the board on a pile of books so that the board makes an inclined plane. Obtain a toy cart and place some stones in it to give added weight. Tape the stones to the cart so they will not fall out, and then weigh the cart and stones with a spring balance.

Now attach the spring balance to the cart

and pull it slowly up the board, keeping the balance horizontal with the board while you are pulling (Figure 17–17). Note that much less force is needed to pull the cart up the incline than to lift it straight up into the air, but the cart must now be moved a longer

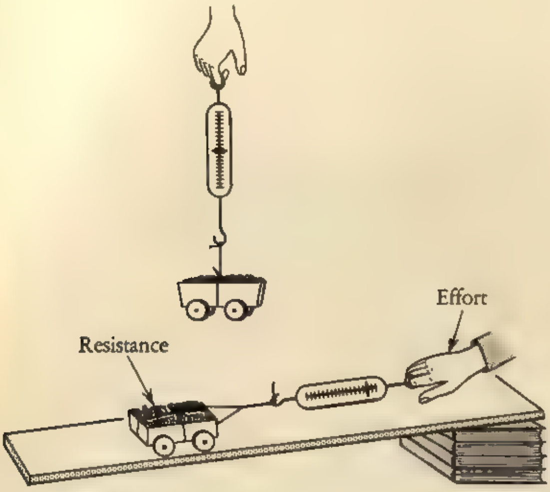


FIGURE 17–17.
LESS FORCE IS NEEDED WITH AN INCLINED PLANE.

distance to reach the same height. Find the height of the inclined plane by measuring the vertical distance from the higher end of the board to the surface upon which the books are resting. Calculate the amount of work done, both input and output. Find the ideal and actual mechanical advantage, and determine the efficiency of the inclined plane.

Make the slope of the inclined plane steeper, either by using a shorter board or by adding more books to the pile. Note the increase in force needed to pull the cart up the incline. Have the children locate and identify examples of inclined planes around them.

15. *Wedge* · Make two wedges by sawing diagonally in half a block of wood 8 inches long, 4 inches wide, and 2 inches thick (Figure 17–18). Hold up one wedge to show that it really is an inclined plane. Place both wedges back to back and form a double inclined plane. Measure the length of the wedge and the thickness of the big end, and then calculate the ideal mechanical advantage. Insert the sharp end of the wedge a short distance under a pile of books and tap the thick end with a hammer, driving the wedge into the pile of books and lifting them. Have the children locate and identify examples of single and double wedges.

16. *Screw* · Cut out a right triangle from a sheet of white paper. Make the base of the

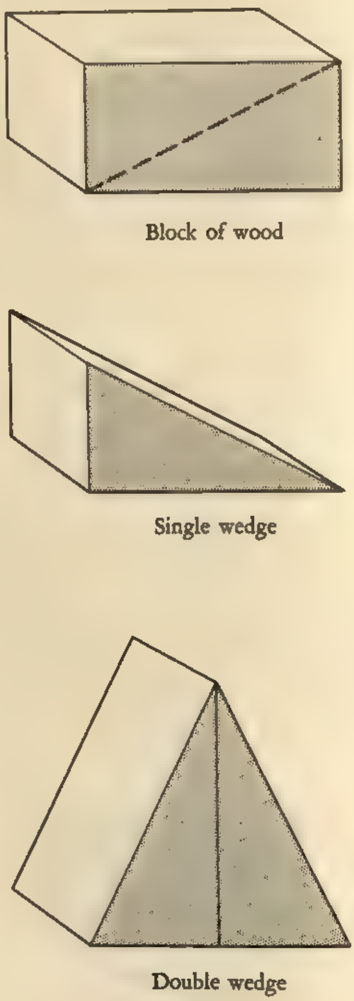


FIGURE 17–18.
MAKING A SINGLE AND A DOUBLE WEDGE.

triangle 8 inches and the height 5 inches in length. Hold up the triangle and show that it is an inclined plane. Make a heavy black line along the hypotenuse, or diagonal side, of the triangle. Starting with the 5-inch side, wrap the paper triangle around a pencil so that the heavy black line shows up clearly as a spiral (Figure 17–19). Hold up a large wood

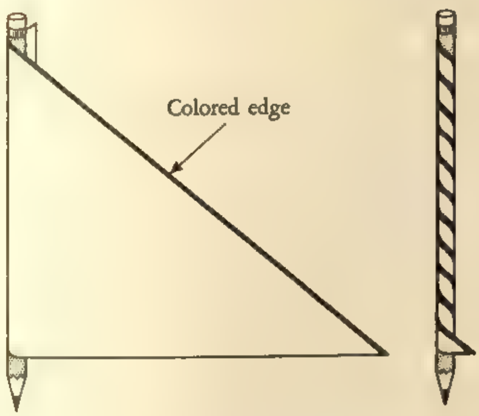


FIGURE 17–19.
A SCREW IS A SPIRAL INCLINED PLANE.

screw beside the pencil and show the similarity between the paper spiral and the screw. Point out the thread of the screw, and then find the pitch by measuring the distance between two threads. Have the children locate and identify examples of screws.

17. *Compound machines* · Have the children identify the simple machines that make up such everyday compound machines as the scissors, can opener, pencil sharpener, meat grinder, water faucet, and wrench.

18. *Wheels and belts* · Obtain a rectangular block of wood about ¾ inch thick and two spools of the same size. Place the spools a few inches apart on the wood, insert loose-fitting nails into the holes of the spools, and drive the nails into the wood. Slip a wide rubber band over both spools (Figure 17–20). Have a child give one spool a complete turn. Note that the other spool also makes a complete turn, moves at the same speed, and turns in the same direction.

Now cross the rubber band so that it makes a figure 8, and have the child give one spool a complete turn again. This time the driven spool will turn in the opposite direction.

Repeat both activities, using a smaller and a larger spool this time. When the larger spool drives the smaller spool and makes one complete turn, the smaller spool turns more than once and moves faster. When the smaller spool drives the larger spool and makes one complete turn, the larger spool turns less than once and moves more slowly. Point out that the fan belt in an automobile is one example of a belt turning a wheel.

19. *Gears with chains* · Turn a bicycle upside down. Push the pedal with your hand and point out how the pedal turns the large gear wheel, which turns the chain, which turns the small gear wheel, which then turns the rear bicycle wheel. One turn of the large gear wheel makes the small gear wheel turn more than

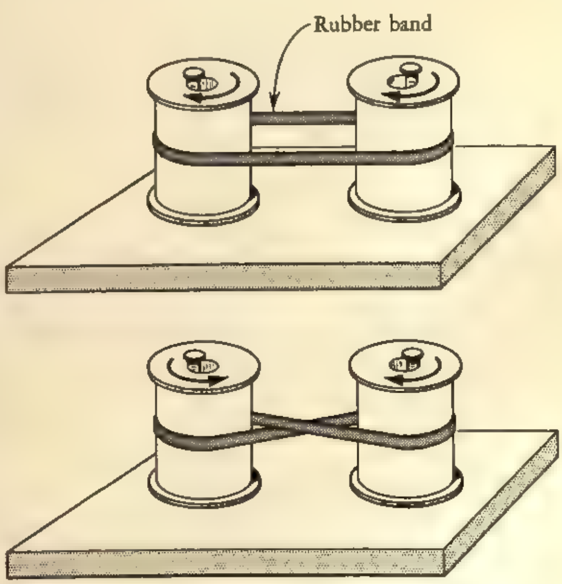


FIGURE 17–20.
A BELT MAKES IT POSSIBLE FOR ONE WHEEL TO TURN ANOTHER WHEEL.

once and move faster. Compare the number of teeth in each gear and find the ideal mechanical advantage.

20. *Gears without chains* · Have the children examine a hand-driven egg beater. Operate the beater slowly and see how the teeth of one gear fit into the notches of another gear and make the second gear turn. Note that when the large hand-driven gear makes one complete turn, the twin stirring gears make several turns and move faster. Also, note that the stirring gears move in opposite directions.

Use black crayon to place a mark on each gear. Make one complete turn of the large gear and see how many turns the smaller stirring gears make. Count the number of teeth on the large and small gears, and find the ideal mechanical advantage of the egg beater.

21. *Windmills* · Make a pinwheel by cutting out a sheet of paper 6 inches square and making lines and pin holes as shown in Figure 17–21. Cut each line, and then bend in the corners to bring the pin holes in line with the center hole of the paper. Run a pin through the pin holes, and then push the pin into the eraser on a pencil or into a cork stopper. Blow on the pinwheel or hold it in front of an electric fan. Point out that the air turns the pinwheel because the air strikes the curved blades at a slant. A windmill operates in much the same way.

Have the children read about and report on windmills and their uses. Point out that the windmill is a wheel-and-axle machine.

22. *Water wheels* · Have the children read and report on different kinds of water wheels. Draw on the chalkboard simplified drawings of the three most common water wheels (overshot, undershot, and breast). Describe their method of operation, note the conditions under which each one operates best, and discuss some of their uses.

23. *The water turbine* · Repeat Learning Activity 19 of "Water," Chapter 11 (p. 378), showing how a water turbine operates. Discuss the uses of the water turbine and compare it with the water wheel.

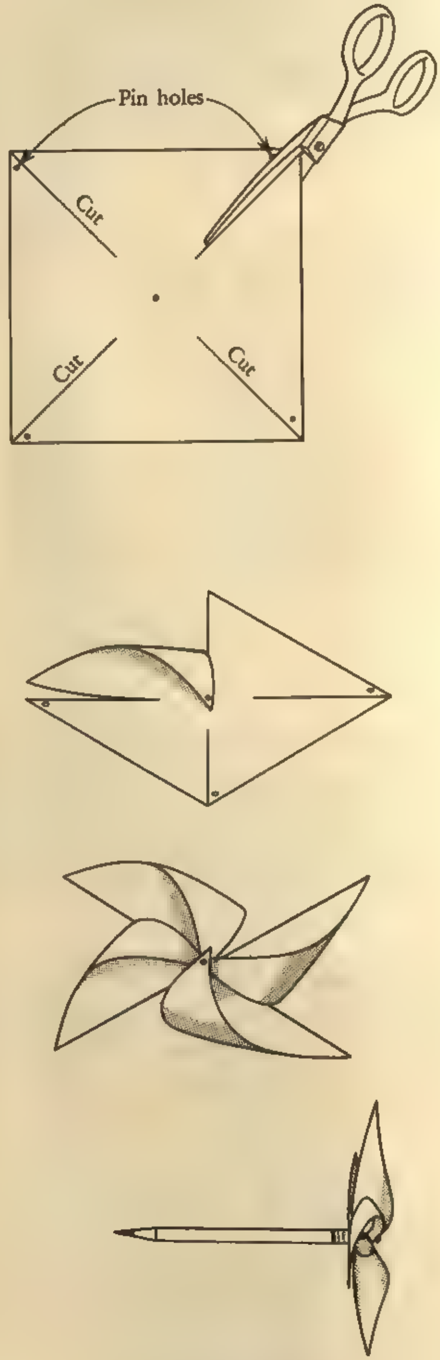


FIGURE 17–21.
MAKING A WINDMILL.

24. *The steam engine* · Have the children read about and report on the steam engine. Draw a diagram or construct a cardboard model of a steam engine and show how each part operates. Simple reproductions of the steam engine can be found in most general science textbooks. Discuss the uses of the steam engine and list its advantages and drawbacks.

25. *The steam turbine* · Repeat Learning Activity 20 of "Water," Chapter 11 (p. 379), showing how a steam turbine operates. Discuss the uses of the steam turbine and compare it with the water turbine.

26. *The carburetor* · Place some alcohol or lighter fluid in an atomizer and spray the fluid into the air once or twice to show how quickly the liquid becomes a vapor when it is broken up into tiny droplets. Now spray the fluid over a candle flame located about 6 inches away, and note the vigorous, almost explosive, flame produced by the rapid-burning fluid (Figure 17–22). (*Caution!* Keep the children well away from the candle!) Point out that the carburetor in an automobile also changes the gasoline into a vapor and mixes it with air to make a rapid-burning mixture.

27. *The gasoline engine* · Draw a diagram or make models of gasoline engine cylinders. Demonstrate all four strokes of the piston, showing the positions of the piston and valves for each stroke. Excellent reproductions of these four strokes can be found in most general science textbooks. Have the children locate examples where gasoline engines are used, and find out how many cylinders these engines have.

28. *The Diesel engine* · Draw a diagram or make models of Diesel engine cylinders. Demonstrate the strokes of both the older four-stroke cycle and the newer two-stroke cycle Diesel engines. Compare the cylinder operation of the Diesel engine with that of the gasoline engine. Discuss the advantages and drawbacks of the Diesel engine and how they affect use.

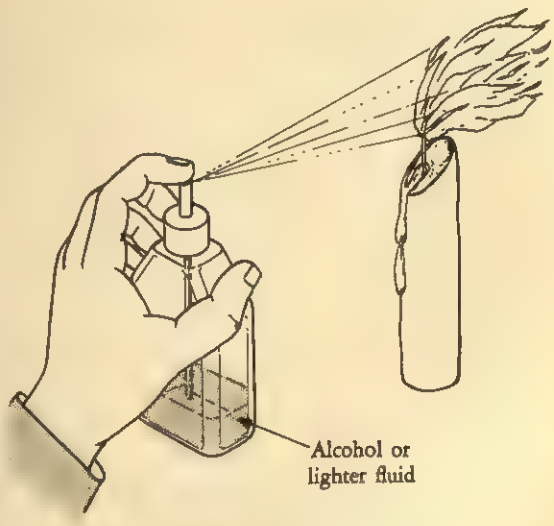


FIGURE 17–22.
SPRAYED FUEL PRODUCES A VIGOROUS FLAME.

BIBLIOGRAPHY FOR "FRICTION AND MACHINES"

ADLER, IRVING. *Tools in Your Life.* New York: Day, 1956. 128 pp.
BLOUGH, GLENN O. *Doing Work.* New York: Harper, 1959. 36 pp.
BUEHR, WALTER. *The First Book of Machines.* New York: Watts, 1962. 69 pp.
BURNS, WILLIAM A. *Man and His Tools.* New York: McGraw, 1956. 158 pp.
DARBY, GENE. *What Is a Simple Machine?* Chicago: Benefic, 1961. 48 pp.

EPSTEIN, SAM, and BERYL EPSTEIN. *All About Engines and Power*. New York: Random, 1962. 144 pp.

HARTMAN, GERTRUDE. *Machines and the Men Who Made the World of Industry*. New York: Macmillan, 1939. 278 pp.

LIBERTY, GENE. *The First Book of Tools*. New York: Watts, 160. 62 pp.

MANN, MARTIN. *How Things Work*. New York: Crowell, 1960. 146 pp.

MEYER, JEROME S. *Engines*. Cleveland: World Pub., 1962. 78 pp.

———. *Machines*. Cleveland: World Pub., 1958. 64 pp.

PARKER, BERTHA M. *Machines*. New York: Harper, 1959. 36 pp.

PINE, TILLIE S., *and* JOSEPH LEVINE. *Friction All Around*. New York: McGraw, 1960. 48 pp.

SHARP, ELIZABETH N. *Simple Machines and How They Work*. New York: Random, 1959. 84 pp.

VICTOR, EDWARD. *Friction*. Chicago: Follett, 1962. 32 pp.

———. *Machines*. Chicago: Follett, 1962. 32 pp.

WYLER, ROSE, and GERALD AMES. *What Makes It Go?* New York: McGraw, 1958, 64 pp.

ZIM, HERBERT S. *What's Inside of Engines?* New York: Morrow, 1953. 32 pp.

ZINER, FEENIE. *About Wonderful Wheels*. Chicago: Children, 1959. 24 pp.

CHAPTER

Heat, Fire, *and* Fuels 18

THE NATURE OF HEAT

I. Kinetic Theory of Heat

A. All materials, or substances, are made of tiny particles, called **molecules.**
B. These molecules are always moving.
C. The movement of these molecules is called heat.
D. The energy that these molecules have is called **kinetic energy (energy of motion).**
1. The faster the molecules of a material are made to move, the more kinetic energy they have, and the hotter the material becomes.
2. The slower the molecules of a material move, the less kinetic energy they have, and the cooler the material becomes.
E. Heat, then, is a form of energy. It is the energy of moving molecules.

II. Sources of Heat Energy

A. **Heat energy** can be produced from at least five other kinds of energy.
B. Heat energy can be produced from the **mechanical energy** of friction, compression, or percussion.
1. When two surfaces are rubbed together, friction makes the molecules move faster, and the materials become hotter.
2. When molecules of gas are crowded together, or compressed, heat is produced.
3. When a hammer pounds a piece of iron, the molecules of iron move faster and have more kinetic energy, so the iron becomes warmer.
C. Heat energy can be produced from **chemical energy.**
1. When two materials react chemically, often the chemical energy that is released is changed, or transformed, into heat.
2. The burning of fuels, such as oil, gas, coal, and wood, is a chemical action that produces heat.
D. Heat energy can be produced from **electrical energy.**
1. When an electric current flows through a thin wire of a light bulb or a toaster, heat is given off.
2. The resistance of the wire to the flow of electric current produces heat.
E. Heat energy can be produced from the **radiant energy** of the sun or other glowing materials.
1. The sun is our chief source of heat, either directly from the sun itself or indirectly as a result of the sun's energy stored up in fuels.
2. Radiant energy, then, is our chief source of heat energy on earth.
F. Heat energy can be produced from **atomic or nuclear energy.**
1. Scientists have discovered that the nu-

cleus of the atom is a tremendous storehouse of energy.

2. When the nucleus of an atom is split, either naturally or artificially, this nuclear energy can be transformed into vast amounts of heat energy.

III. Effect of Heat upon Changes in the State of Matter

A. All materials are found in any one of three forms, or states, of matter: solid, liquid, or gas.
   1. In gases the molecules have very much energy. They move very fast and are very far apart.
   2. In liquids the molecules have less energy. They move less quickly and are closer together.
   3. In solids the molecules have much less energy. They are very close together, and each molecule seems to vibrate at one spot rather than move about.

B. Water is a material that we can usually find in all three forms, or states.
   1. As ice it is in the form of a solid.
   2. As water it is in the form of a liquid.
   3. As water vapor it is in the form of a gas.

C. We can bring about a change in state of a material by heating or cooling the material.

D. If we add heat energy to a solid, the solid becomes a liquid.
   1. The added heat energy makes the molecules in the solid vibrate more and more quickly until they finally break away and move about freely and are farther apart, as in a liquid.
   2. When this condition occurs we say the solid melts, and the temperature at which melting takes place is called the melting point.
   3. Every solid has its own melting point.

E. If we take heat energy away from a liquid, the liquid becomes a solid.
   1. Taking away heat energy makes the molecules move more slowly and come closer together until they are very close together, and each molecule vibrates at one spot rather than moves about.
   2. When this condition occurs we say the liquid freezes, and the temperature at which freezing takes place is called the freezing point.
   3. Every liquid has its own freezing point, but usually a material has the same melting and freezing points, depending upon whether heat is being added or taken away.
   4. Butter is an exception to this rule, having a different melting and freezing point. It melts at a higher temperature and freezes at a lower temperature.

F. If we add heat energy to a liquid, the liquid becomes a gas.
   1. The added heat energy makes the molecules in the liquid move more quickly and stay farther apart until they are moving very quickly and are very far apart, as in a gas.
   2. When this condition occurs we say the liquid evaporates, or turns into a gas or vapor.
   3. Evaporation takes place at all temperatures, but, if a liquid is heated hot enough, at a certain temperature bubbles of gas form, which rise to the surface of the liquid.
   4. When bubbles form in this way, we say that the liquid boils, and the temperature at which boiling occurs is called the boiling point.
   5. Every liquid has its own boiling point.

G. If we take heat energy away from a gas, the gas becomes a liquid.
   1. Taking away heat energy makes the gas molecules move more slowly and come closer together until the gas condenses, or turns into a liquid.
   2. Every gas has its own temperature at which it will become a liquid.
   3. Usually a material boils or goes from a gas to a liquid at the same temperature, depending upon whether heat is being added or taken away.

IV. Expansion and Contraction

A. When materials are heated, the molecules move faster and spread farther apart so that the materials become bigger, or expand.

B. When materials are cooled, the molecules move more slowly and come closer together so that the materials become smaller, or contract.

C. The rate of expansion and contraction is different for solids, liquids, and gases.

1. In solids the molecules are very close together and seem to vibrate rather than move, so solids expand and contract the least.
2. In liquids the molecules move about quickly and are farther apart, so liquids can expand and contract more than solids.
3. In gases the molecules move about very quickly and are very far apart, so gases expand and contract the most.

D. The rate of expansion and contraction differs between solids and between liquids.

1. Because the molecules in all solids at the same temperature do not move at the same speed, some solids expand and contract more than other solids.
2. The same is true of liquids.
3. In gases the molecules are so far apart and move so fast that they all expand and contract about the same.

V. Exceptions to the Rule of Expansion and Contraction

A. Almost all materials expand when heated and contract when cooled.

B. Water is an exception to this rule.

1. When water is cooled, it contracts until the temperature of the water reaches 39 degrees Fahrenheit (F).
2. From 39 degrees Fahrenheit to 32 degrees Fahrenheit (the freezing point of water), water now expands slightly as it is cooled.
3. Because water also expands as it freezes, ice is lighter than water and floats on top of the water.
4. This unusual form of expansion explains why the water in a lake freezes from the top down rather than from the bottom up.
5. This unusual form of expansion also explains why water pipes burst when the temperature is below freezing.

C. Rubber is also an exception to the rule because it contracts when heated gently and expands when cooled.

VI. Expansion and Contraction in Our Daily Life

A. When the metal lid of a glass jar is stuck tight, hot water makes the lid expand more than the jar, and the lid can unscrew easily.

B. When two glass tumblers are stuck, one inside the other, they can be loosened by pouring hot water on the outside tumbler while filling the inside tumbler with cold water.

C. When baking powder is used in baking a cake, carbon dioxide gas forms inside the dough and expands when heated, causing the cake to rise.

D. Telephone wires that are strung in summer are allowed to sag a little so that the wires can contract in winter.

E. Engineers place one end of a bridge on rollers to allow for expansion and contraction of the bridge in summer and winter.

F. Railroad tracks are laid with a small space between the end of one rail and the beginning of the next rail to allow the rails to expand and contract when the temperature changes.

G. Workmen leave small spaces between slabs of concrete road and sidewalk so that the concrete will not expand and bulge in the summer or contract and crack in the winter.

H. Metal rivets used in construction are hammered into place while red hot so that, when they cool, they will contract and pull the parts together with great force.

I. A blacksmith fits an iron rim on a wagon wheel when the rim is very hot so that, when the rim cools, it will contract and fit very tightly on the wheel.

J. Some thermometers have liquids inside them, which expand and rise up the thermometer tube when they are heated, and then contract and fall down the tube when they are cooled.

K. Thermostats and metallic thermometers contain a bar or coil made of strips of two different metals that expand at different rates, causing the bar or coil to turn when heated or cooled.

TEMPERATURE

I. Temperature

A. **Temperature** describes how hot or cold a material is.

B. Temperature has nothing to do with the amount of heat a material has; it only has to do with the degree of "hotness" or "coldness" of the material.

C. Temperature depends upon the speed that the molecules in a material are moving.

1. The faster the molecules are moving, the hotter the material becomes, and the higher the temperature of the material will be.
2. The slower the molecules move, the colder the material becomes, and the lower its temperature will be.

II. Measurement of Temperature

A. A **thermometer** is used to measure temperature.

B. The operation of a thermometer depends upon the principle that materials expand when they are heated and contract when they are cooled.

C. The thermometer we commonly use to measure temperature is a sealed glass tube with a liquid such as mercury or colored alcohol in it.

1. There is a very narrow, hollow passageway running up and down the tube. This passageway is called the **bore**.
2. At the bottom of the bore is a bulb that contains the liquid.
3. The liquid is also part of the way up the bore.
4. When the liquid inside the bulb is heated, it expands and rises up the bore.
5. When the liquid is cooled, it contracts and goes down the bore.

III. Temperature Scales

A. A **scale** on the thermometer tells us just how high the liquid is in the thermometer, and gives us the temperature of whatever is around the bulb.

B. The scale on a thermometer is divided into many equal lines, or divisions, called degrees.

C. The degree (°) is the unit of measurement of temperature.

D. The two common temperature scales are the **Fahrenheit** and the **Centigrade**, or **Celsius**, scales.

E. In the Fahrenheit scale the freezing point of water registers at 32° and the boiling point of water registers at 212°.

1. There are 180 lines, or divisions, between the freezing point and boiling point of water.
2. Zero on the Fahrenheit scale is the lowest temperature the inventor (Fahrenheit) could get from a mixture of salt and ice in water.

3. The Fahrenheit scale is used by most English-speaking countries.

F. In the Centigrade scale, now called the Celsius scale, the freezing point of water is at 0° and the boiling point of water is at 100°.
   1. There are 100 lines, or divisions, between the freezing point and boiling point of water.
   2. The rest of the world and all scientists use the Centigrade scale.

G. It is possible to change from the Fahrenheit scale to the Centigrade scale, and vice-versa.
   1. Because there are 180 Fahrenheit degrees and 100 Centigrade degrees between the freezing and boiling points of of water, 1° F is equal to $^{100}/_{180}$, or $5/9$° C; and 1° C is equal to $^{180}/_{100}$, or $9/5$° F.
   2. Also, because 0° on the Centigrade scale is the same as 32° on the Fahrenheit scale, we must always *subtract* 32° when changing from the Fahrenheit to the Centigrade scale, and always *add* 32° when changing from the Centigrade to the Fahrenheit scale.
   3. So, to change from °F to °C, subtract 32° from the Fahrenheit reading and multiply the result by $5/9$.

$$C = (F - 32) \times \frac{5}{9}$$

   4. To change from °C to °F, multiply the Centigrade reading by $9/5$ and add 32°.

$$F = \frac{9}{5}C + 32$$

IV. Kinds of Thermometers

A. *Mercury thermometer*
   1. This thermometer has mercury, the only liquid metal at room temperature, in it.
   2. Because mercury has a high boiling point (about 675° F), the mercury thermometer is used to measure fairly high temperatures.
   3. However, mercury freezes at 40° below zero Fahrenheit, so it cannot be used to measure very low temperatures.

B. *Alcohol thermometer*
   1. An alcohol thermometer looks and operates exactly like the mercury thermometer, except that alcohol—colored red or blue—is in the bulb and tube.
   2. Since alcohol has a boiling point lower than that of water (about 172° F), the alcohol thermometer cannot be used to measure high temperatures.
   3. However, alcohol has a very low freezing point (about 202° below zero Fahrenheit), so the alcohol thermometer is used in arctic and polar regions.
   4. Most indoor and outdoor household thermometers are alcohol thermometers.

C. *Clinical thermometer*
   1. The clinical thermometer is a mercury thermometer, but is shorter than the regular mercury thermometer.
   2. The scale on the clinical thermometer runs only from 92° F to 110° F.
   3. The bore, or hollow passageway, of this thermometer is very narrow so that even one tenth of a degree will make a big difference in the level of the mercury and can easily be read.
   4. At one spot inside the bore there is a narrow bend or pinch.
   5. When the clinical thermometer is placed inside a person's mouth, the mercury is heated and expands, pushing its way up and beyond this pinch to give the proper temperature reading.
   6. When the thermometer is removed, however, the mercury cannot fall back through the pinch, so the level of the mercury stays at the temperature of the person's body.
   7. This stationary position allows the doctor to get an accurate reading of the person's body temperature.
   8. The only way to force the mercury down the tube again, past the pinch, is to shake the thermometer quite vigorously a few times.

D. *Metal thermometer*
1. This thermometer does not have a glass tube, bulb, or liquid in it.
2. It has a small coil made of two strips of metal welded together along their lengths.
3. The inside strip of metal is usually brass, and the outside strip is steel.
4. When the coil is heated or cooled, the brass strip expands and contracts more than the steel strip, and makes the coil twist.
5. As the coil twists, a pointer connected to one end of the coil moves across a scale that is marked off in degrees.

V. Uses of Thermometers

A. Thermometers are used in the home to take the temperature indoors or outdoors, to take body temperature, and to test the temperature of cooking food.

B. Thermometers are used in industry by dairies, ice cream manufacturers, candy manufacturers, florists, and all organizations that use scientists.

VI. Measurement of the Amount of Heat

A. There are two units commonly used to measure the amount of heat: the **British thermal unit (Btu)** and the **calorie.**

B. The British thermal unit is the amount of heat needed to raise the temperature of 1 pound of water 1 degree on the Fahrenheit scale.

C. The calorie is the amount of heat needed to raise the temperature of 1 gram (about two-thousandths pound) of water 1 degree on the Centigrade scale.
1. This calorie is called the small calorie and is spelled with a small "c."
2. The large **Calorie,** spelled with a capital "C," is equal to 1000 small calories.
3. We use large Calories to find out how much heat energy we get from different foods.

METHODS OF HEAT TRAVEL AND THEIR EFFECTS

I. Heat Can Travel by Conduction

A. When a material such as a metal rod is heated, the molecules next to the source of heat move faster.

B. The molecules bump into other molecules, making them move faster.

C. These molecules then bump into still other molecules, making them move faster too.

D. In this way all the molecules in the material are made to move faster and have more kinetic energy, so the material becomes hotter.

E. The heat energy has been passed, or conducted, from molecule to molecule within the material, yet the material itself does not move.

F. This method of heat travel, where energy is passed along from molecule to molecule by bumping, or collision, is called **conduction.**

G. Any material through which heat travels is called a **conductor.**
1. Metals are good heat conductors.
2. Good heat conductors are also good conductors of electricity.
3. In good heat conductors the molecules are very close together and conduct the heat energy from molecule to molecule very quickly and easily.
4. Some metals, such as silver and copper, are better heat conductors than other metals.

H. Materials that do not conduct heat very well are called **nonconductors,** or **poor conductors.**
1. Most nonmetals, liquids, and gases are poor conductors of heat.

2. In poor heat conductors the molecules are farther apart and do not conduct the heat energy from molecule to molecule quickly or easily.

I. A vacuum cannot conduct heat because there are no molecules to pass along the heat energy.

J. When a nonconductor is used to stop the conduction of heat, it is called an **insulator.**

1. The handles of pots and pans are covered with insulators made of wood or plastic.
2. Rubber and cloth are also used as insulators.
3. Because air is a very poor heat conductor, anything with air spaces in it, such as wool, cork, or asbestos, is a good insulator.

II. Heat Can Travel by Convection

A. **Convection** is a method of heat travel that takes place only in gases and liquids, which are called fluids.

B. When a fluid such as air is heated, the molecules move faster and spread farther apart so that the air expands.

1. When air expands, it becomes lighter.
2. The colder air above it is heavier, and gravity pulls down harder on the colder, heavier air than on the warmer, lighter air.
3. Because of this greater pull of gravity, the cold air moves down and pushes the warm air upward.
4. This cold air in turn is heated, expands, becomes lighter, and is pushed upward by colder, heavier air above it.
5. In this way continuous currents of rising and falling air are produced.
6. The same currents are produced with a fluid such as water.

C. Convection, then, is a method of heat travel where the molecules of heated gas or liquid actually move from one place to another.

1. The heat is carried from a place of higher temperature to a place of lower temperature by the molecules of moving gas or liquid.
2. The movement of the gas or liquid is called a **convection current.**

III. Heat Can Travel by Radiation

A. **Radiation** as a method of heat travel is very different from conduction and convection because it has nothing to do with the passing of heat by moving molecules.

B. The sun and other glowing bodies give off, or radiate, energy in the form of invisible waves.

1. These radiant energy waves travel out into space without the help of molecules.
2. When the radiant energy strikes a solid, opaque material, the energy is absorbed and makes the molecules in the material move faster so the material becomes hotter.
3. The radiant energy is not heat, but becomes heat when it is absorbed.
4. The sun heats the earth 93 million miles away in this way.

C. This method of passing along heat by radiant energy waves is called **radiation.**

D. The kind of material decides how much radiant energy is changed into heat.

1. Dark, rough materials are good absorbers of radiant energy and produce much heat.
2. Light, smooth materials reflect most of the radiant energy that strikes them, and so do not produce much heat at all.
3. Transparent materials, such as air and glass, allow almost all of the radiant energy to pass through them, so these materials produce little or no heat.

E. Radiant heat waves are part of a family of radiant energy waves called **electromagnetic waves.**

1. This family includes radio waves, infrared rays or heat waves, light rays, ultraviolet rays, X-rays, gamma rays, and cosmic rays.
2. All of these electromagnetic waves travel at a speed of 186,000 miles a second,

but they all differ in the length of their waves and in the number of times a second these waves vibrate (their frequency).

IV. HEATING THE HOME

A. *The fireplace*

1. When a fire is started in a fireplace, the heat of the fire warms the air in the fireplace and the air in the chimney.
2. A convection current is produced, which moves through the fireplace and up the chimney.
3. This convection current removes cold air from the floor, but the current also carries much of the heat of the fire up the chimney.
4. The heat that warms the room is mostly radiant heat, where the radiant energy from the fire is absorbed by the walls, furniture, and other materials in the room.

B. *The stove*

1. The heat from the fire in the stove passes through the metal walls by conduction, and also into the air next to the walls by conduction.
2. The heated air sets up a convection current that heats the whole room.
3. The hot walls of the stove radiate some heat as well.
4. Gas, oil, kerosene, coal, and wood can be used as fuel for a stove.
5. Today most stoves use gas or electricity, for cooking purposes only.

C. *Central heating systems*

1. Most homes and buildings are heated by central heating systems.
2. In central heating systems the stove, or furnace, is located in the basement or utility room.
3. The heat is conducted from the furnace to the rooms by pipes or ducts.
4. The most commonly used central heating systems today are: the **hot-air, hot-water, steam,** and **radiant heating** systems.

D. *The hot-air heating system*

1. In the hot-air heating system the furnace is surrounded by a brick or iron jacket filled with air.
2. The furnace heats the jacket by conduction, and the jacket heats the air by conduction.
3. The hot air inside the jacket is pushed up either by cold air entering at the bottom of the furnace or by a fan.
4. The hot air goes up the pipes into the different rooms in the house.
5. The hot air comes into each room through a metal grating, or register, in the floor or the walls.
6. The air circulates through the rooms and heats them by convection.
7. Then the air is either carried back to the furnace through a cold-air return so that it can be reheated, or the air is allowed to escape and is replaced by fresh air from outdoors.

E. *The hot-water heating system*

1. In the hot-water heating system the furnace is surrounded by a boiler filled with water.
2. When the water is heated, it is pushed up by cold water entering the bottom of a boiler.
3. The hot water goes up the pipes into the different rooms in the house.
4. The hot water goes into a metal radiator in each room.
5. The radiator is divided into many sections of hollow pipe so that the radiator exposes a great deal of surface to the air.
6. The hot water heats the walls of the radiator by conduction.
7. The radiator walls heat the air next to them by conduction.
8. The hot air then heats the room by convection.
9. At the same time the radiator radiates some heat as well.
10. After the hot water in the radiator gives up its heat and becomes cooler, it goes back to the boiler through return pipes and is reheated.

11. The same water is used over and over again.

F. *The steam heating system*

1. The steam heating system works very much like the hot-water heating system except that steam is used instead of hot water.
2. The boiler is only partly filled with water.
3. When the water is heated, it is changed into water vapor or "steam."
4. The steam has great pressure and is forced up the pipes into the radiators.
5. When the steam gives up its heat to the radiators, it condenses back into water, which goes down the pipes to the boiler, where it is reheated.

G. *The radiant heating system*

1. In this system hot water is circulated through copper pipes located in the floor or walls.
2. The hot water heats the pipes by conduction.
3. The pipes heat the floors and walls by conduction.
4. The floors and walls radiate much heat energy, and this radiant energy heats the people and furniture in the room.

H. *Solar heating*

1. In some parts of the country the sun is used to furnish part of the heat needed for the home.
2. The sides of the building facing the sun are mostly large glass windows.
3. Radiant energy from the sun passes through the windows into the rooms, where the radiant energy is absorbed and changed into heat.
4. Solar heating works well on clear days when it is not too cold or windy.
5. At night a regular heating system must be used.

I. *The heat pump system*

1. The heat pump system gets its heat from the earth.
2. A pump run by an electric motor makes water flow through long pipes in the earth outside the house.
3. The flowing water takes heat from the earth and brings it into the house.
4. In the summer the pump cools the house by having the flowing water take heat from the house and bring it to the earth outside.

V. Insulating the Home

A. There are three ways in which heat is lost in the home.

1. Heat is conducted through the windows, walls, and roof.
2. Heat is radiated through the windows.
3. Heat escapes through cracks around doors and windows.

B. This heat loss can be prevented in many ways.

C. Insulating materials can be used in the walls and under the roof.

1. These materials, such as rock wool or glass wool, have many air spaces in them, and are nonconductors, or **insulators.**
2. These materials stop heat from being conducted out through the walls and roof.

D. Storm windows, when fitted over regular windows, create an air space between the two windows.

1. Air is a poor conductor of heat and acts as an insulator.
2. This insulation prevents the windows from conducting heat out of the house.

E. Weather strips or special materials, when placed around windows and doors, stop heat from escaping through any cracks that might be present.

F. Insulation not only stops heat from leaving the house in the winter, but helps keep heat from getting into the house in the summer.

VI. Cooling in the Home

A. *The refrigerator*

1. The refrigerator cools by taking heat away from materials.

2. The refrigerator has a pipe running through it.
3. Inside the pipe is a gas called **Freon,** which is changed into a liquid very easily when it is compressed.
4. In the electric refrigerator a motor runs a compressor, which compresses the Freon and takes heat away from it until the gas becomes a liquid.
5. The heat that is taken away from the gas passes out into the air of the room.
6. The liquid Freon then flows under pressure through the pipe in the refrigerator until it reaches the ice cube or freezer compartment.
7. Here the pressure is taken away from the liquid Freon so that the liquid evaporates into a gas again.
8. When a liquid evaporates, it needs heat, and takes this heat from the space surrounding the liquid.
9. Taking heat away will cool the materials in the space surrounding the liquid that is evaporating.
10. The Freon gas then continues to the motor and compressor, where it is turned into a liquid again.

B. *The deep freeze*

1. Special refrigeration machines freeze food quickly until the temperature of the food in the machines is 10 to 20 degrees below zero Fahrenheit.
2. The freezing must be quick, or else the food will lose much of its flavor and consistency.
3. When food is frozen, the water in the food freezes and forms ice crystals.
4. When food, especially fruits and vegetables, is frozen slowly, the ice crystals are large and break the cells of the food, killing their taste and flavor.
5. When the food is frozen quickly, the ice crystals are very small and do not break the food cells.

VII. Air Conditioning

A. An efficient air conditioner accomplishes four things.

1. It cools the air in the room.
2. It lowers the amount of water vapor (humidity) in the air.
3. It cleans the air.
4. It supplies fresh air and removes stale air.

B. The air conditioner has a cooling unit that acts just like a refrigerator.

1. The warm air passes through the cooling unit, and the heat is taken away from the air.
2. This heat is passed on to the air outdoors, which carries it away.

C. A special dehumidifying apparatus helps the excess water vapor in the air condense out as the air is cooled.

D. The air is blown by a fan through a filter, which removes dust and pollen.

E. The air conditioner usually has a fresh-air connection, which provides the conditioner with fresh outdoor air.

FIRE

I. The Nature of Fire

A. Fire is the burning of a material, and is also called **combustion.**

B. Fire is a chemical change that takes place when certain materials combine rapidly with oxygen to give off heat and light.

C. This chemical reaction, which takes place when a material combines with oxygen, is called **oxidation.**

D. Materials can also combine slowly with oxygen and produce some heat, but no light.

1. This combination is oxidation, too, but

it is a slow oxidation and is not called burning or combustion.

2. The rusting of iron is an example of slow oxidation.
3. To be called burning, the oxidation must be fast enough to produce both heat and light.

II. Factors Necessary to Produce Fire

A. For burning to take place, three things are needed: **fuel, oxygen,** and **heat.**

B. A fire needs a material that will burn, which is called a **fuel.**

C. A fire needs **oxygen.**
1. Oxygen is one of the gases in the air.
2. The more oxygen a fuel gets, the faster the oxidation will take place, and the hotter the fire will become.
3. Supplying the fire with more air will give the fuel more oxygen.
4. Breaking the fuel into small pieces will expose more of the fuel's surface to the air, and in this way give the fuel more oxygen.
5. If a fuel is broken up into pieces so small that the pieces look like particles of dust, the fuel may combine with the oxygen so quickly that it will produce an explosion.

D. A fire needs enough heat to get the fuel hot enough to burn.
1. Some materials burn more easily than others.
2. We say that these materials have a lower kindling temperature.
3. The **kindling temperature** is the lowest temperature at which a material will catch fire and burn.
4. At this temperature the oxygen will combine quickly enough with the fuel to keep the chemical reaction going steadily.
5. Materials like phosphorus, sulfur, and paper have a low kindling temperature, and burst into flame easily.
6. Materials like wood and coal have a high kindling temperature and must be quite hot before they will burn.

III. The Products of Fire

A. Fire produces a **flame.**
1. A flame is a mass of burning gas.
2. Some fuels produce a flame directly, but other fuels must be partially changed into a gas before they can burn with a flame.
3. A gaseous fuel, such as natural gas, burns directly to produce a flame.
4. A liquid fuel, such as gasoline or kerosene, must be heated until it turns into a gas before it will burn.
5. Some solid fuels, like paraffin, first melt and then turn into a gas before they can burn.
6. Other solid fuels, like wood and coal, when heated will give off gases that burn.

B. The color of the flame depends upon how much oxygen the fuel is getting.
1. When a fuel gets all the oxygen it needs and burns completely, the flame is blue and is very hot.
2. When a fuel does not get enough oxygen to burn completely, the flame is yellow or orange and is not as hot as a blue flame.
3. The flame is yellow because the particles of unburned fuel are glowing.

C. A candle flame has three parts to it.
1. The center of the flame around the wick is dark, showing the presence of unburned gas.
2. Almost all the rest of the flame is yellow, which shows that the gas is burning but is not getting all the oxygen it needs.
3. Around the edges the flame is blue or colorless, which shows that here the gas is getting all the oxygen it needs and is burning completely.

D. Fire produces water vapor and carbon dioxide or carbon monoxide gas.

1. Most common fuels contain the chemical elements carbon and hydrogen.
2. When the fuel burns, the hydrogen combines with the oxygen to form water vapor.
3. Water vapor forms instead of liquid water because so much heat is given off during the burning.
4. When the fuel has all the oxygen it needs and burns completely, the carbon combines with the oxygen to form carbon dioxide gas.
5. When the fuel does not get enough oxygen, the carbon combines with the oxygen to form carbon monoxide gas instead.
6. Carbon monoxide gas is made up of less oxygen than carbon dioxide gas.

E. **Smoke** is unburned fuel.
1. Smoke is made up of particles of carbon that did not receive enough oxygen to make them burn completely.
2. When smoke collects on walls or in chimneys, it is called **soot.**

F. Some fuels leave behind an **ash**, which is part of the fuel that does not ordinarily burn.

IV. Spontaneous Combustion

A. Sometimes materials burst into flame all by themselves.
1. This phenomenon is called **spontaneous combustion.**
2. Spontaneous combustion takes place when a slow oxidation is going on in a closed space where the air cannot circulate or escape.

B. An oily rag in a closed closet can often burst into flame by spontaneous combustion.
1. The oil combines with oxygen, or oxidizes, slowly and gives off a small amount of heat.
2. This heat cannot escape because the closet is closed and there is no movement of air to carry the heat away.
3. The heat makes the oil combine with oxygen more quickly, which produces more heat, which cannot escape and so makes the oil combine with oxygen even more quickly.
4. This process goes on and on, producing more and more heat, until the kindling point of the cloth rag is reached, and the rag bursts into flame.

C. If green or wet hay is stored in a barn, spontaneous combustion may take place because the damp hay ferments and gives off heat.

V. Factors Necessary to Put Out Fire

A. To put out a fire we must take away one or more of the three things needed to make a fire.
1. We can remove the fuel.
2. We can cut off the supply of oxygen.
3. We can cool the burning fuel, making its temperature lower than the kindling point.

B. The most common methods of putting out fires try to cut off the supply of oxygen and lower the temperature.

C. Removing the fuel is practical only with a small fire, such as a camp fire or a fire in a waste basket.

D. The supply of oxygen can be cut off by using sand, dirt, a heavy wool blanket or coat, water, carbon dioxide gas, and any other material that will not burn.

E. The temperature can be lowered by using water or any other cool material that will not burn.

VI. Fire Extinguishers

A. Fire extinguishers use chemicals to put out fires by cutting off the supply of oxygen and by cooling the burning fuel.

B. The **soda-acid** fire extinguisher, when turned upside down, mixes two chemicals together to form carbon dioxide gas.
1. The carbon dioxide gas smothers the fire by cutting off the supply of oxygen.
2. This type of extinguisher has water in

it, and cannot be used to put out oil fires because the water is heavier than oil and sinks to the bottom while the burning oil floats and even spreads out further on top of the water.

3. This type of extinguisher also cannot be used to put out electrical fires because the solution of chemicals in the extinguisher is a good conductor of electricity.

C. The **carbon dioxide** extinguisher is used for putting out oil and electrical fires.

1. The extinguisher has compressed liquid carbon dioxide in it.
2. When the liquid carbon dioxide goes out of the extinguisher, it turns into large amounts of very cold carbon dioxide gas.
3. The carbon dioxide gas puts out the fire by cutting off the supply of oxygen and by cooling the burning fuel.

D. The **carbon tetrachloride** extinguisher is also used to put out oil and electrical fires.

1. Liquid carbon tetrachloride is pumped out of the extinguisher.
2. The flames heat the liquid carbon tetrachloride and turn it into a heavy blanket of gas, which pushes the air away from the fire and smothers it.

E. The **foam-type** extinguisher is very effective against gasoline and large oil fires.

1. It works very much like the soda-acid extinguisher, but it also has a foam-making material, such as licorice extract, in it.
2. When the extinguisher is turned upside down, the chemicals mix together and produce a tough foamy mass of carbon dioxide bubbles.
3. This foamy mass of bubbles covers the burning gasoline or oil and shuts off the supply of oxygen.

VII. Some Safety Rules for Fires

A. Keep matches away from heat.
B. Keep matches away from small children.
C. If you have to strike a match, strike away from you and not toward you.
D. Be sure the flame is out when you throw the match away.
E. Surround a campfire with stones, bricks, or bare earth.
F. Be especially careful when making a campfire on a windy day.
G. Put out the campfire thoroughly when you do not want it any more.
H. Never use gasoline to start a fire.
I. Put a metal screen in front of the fireplace.
J. Put hot ashes in metal containers only.
K. Do not allow trash that will burn to pile up in the basement or attic.
L. Do not put oily rags in closets or other places where there is no circulation of air.
M. If a container has materials in it that will burn, keep it away from heat or an open flame.
N. Keep a pail of sand or a wool blanket nearby for putting out small fires.
O. Have a small carbon dioxide fire extinguisher in the home, where it can be quickly reached.
P. If your clothes catch on fire, do not run. Running supplies the fire with more air so the fire burns faster. Roll on the floor or wrap up in a rug, coat, or blanket.
Q. Learn how to telephone the fire department and turn in an alarm in the fire alarm box.
R. If a fire in a house is too big for you to put out, leave the house at once. Close the door to the room where the fire is, to cut down the supply of air in the room. Go to the nearest alarm box or telephone the fire department.

FUELS

I. Characteristics of a Good Fuel

A. A **fuel** is any material that is burned to produce heat for use in the home or in industry.

B. For a material to be considered a good fuel, it should have certain characteristics.
   1. It should be inexpensive and easy to get.
   2. It should be easy and safe to store, ship, and use.
   3. It should burn fairly easily.
   4. It should produce a large amount of heat.
   5. It should produce very little smoke.

C. There are three classes of fuels: solid, liquid, and gas fuels.

II. Solid Fuels

A. Solid fuels include **wood, charcoal, coal, coke, peat,** and **lignite.**

B. Wood is still used very much as a fuel.
   1. It has a low kindling temperature and gives a great amount of heat.
   2. However, wood gives off much smoke and leaves behind a lot of ash.

C. Charcoal is wood that is heated in the absence of air. It is a man-made fuel.
   1. The liquid and gas impurities in the wood are driven off, leaving mostly burnable carbon behind.
   2. Charcoal burns with a great deal of heat, gives off no smoke, and leaves very little ash.

D. Coal is the remains of plants and ferns that were covered by the earth millions of years ago.
   1. Because of the action of high temperatures, and tremendous pressures in the earth, the liquid and gas impurities were driven off, leaving mostly burnable carbon behind.
   2. **Soft** coal has about 70 percent carbon in it and burns with a great deal of heat, but it gives off much smoke and leaves quite a bit of ash.
   3. **Hard** coal has almost 90 percent carbon in it, burns with a great deal of heat, gives off much less smoke, and leaves little ash.

E. Peat and lignite are coal in its early stages of formation, and do not give very much heat.

F. Coke is soft coal that is heated in the absence of air. It also is a man-made fuel.
   1. Gas impurities in the soft coal are driven off, leaving mostly burnable carbon behind.
   2. It burns with a great deal of heat, gives off no smoke, and leaves very little ash.

III. Liquid Fuels

A. **Petroleum,** also known as "crude oil," was formed from the remains of small plants and animals that died millions of years ago.
   1. These remains were buried in mud and rock beneath shallow seas.
   2. Today most of the petroleum is found deep below the earth's surface in certain kinds of rock formations.
   3. In some areas petroleum is also found below the earth's surface a short distance from the seashore.

B. The raw petroleum is not used as a fuel itself, but is broken up into different materials and refined.
   1. From petroleum we get such fuels as **fuel oil, diesel oil, gasoline,** and **kerosene.**
   2. From petroleum we also get such commercially important materials as **naphtha, benzine, lubricating oil, grease,** and **paraffin.**

C. Liquid fuels have replaced much of the solid fuels because they can be stored and shipped easily, burn cleaner and hotter, and leave no ash.

IV. Gas Fuels

A. Gas fuels include **natural** gas and artificial, or man-made, gases.
B. Natural gas is found together with petroleum deposits and also near coal fields.
C. Artificial gases are made from soft coal, coke, and petroleum.
D. All gas fuels have a large advantage over both solid and liquid fuels because they burn instantly.
  1. At the same time gas fuels are clean and easy to handle, and they can be piped all over the country.
  2. Gas fuels also give very much heat, produce no smoke, and leave no ash.

LEARNING ACTIVITIES FOR "HEAT, FIRE, AND FUELS"

THE NATURE OF HEAT

1. *Heat is the energy of moving molecules* · Place a tumbler of cold water and a tumbler of hot water side by side, and add two drops of red food coloring to each tumbler. Point out that the molecules of hot water have more kinetic energy and are moving more quickly than the molecules of cold water. These faster moving molecules of hot water disperse the food coloring more quickly than the slower moving molecules of cold water.

2. *Friction is a source of heat* · Have the children rub the palms of their hands together briskly and note the heat produced by the resulting friction.

3. *Compression is a source of heat* · Use a hand pump to inflate a bicycle tire or a football. Point out that the barrel of the pump becomes warm because the air inside has been compressed.

4. *Percussion is a source of heat* · Pound a block of iron or other metal with a hammer. The continued percussion makes the molecules of iron move faster, and the block becomes warmer.

5. *Chemical energy is a source of heat* · Strike a match and make it burn. Note that the friction of the match head rubbing against a rough surface produces enough heat to cause a chemical reaction to take place. The match head bursts into flame, and the chemical energy of the burning match is a source of heat.

6. *Electrical energy is a source of heat* · Turn on a hot plate or electric toaster, showing that electrical energy is being converted to heat energy.

7. *Radiant energy is a source of heat* · Place a match head on a Pyrex pie plate and use a magnifying glass to focus the sun's rays on the match head. The match head will burst into flame.

8. *Nuclear energy is a source of heat* · Have the children read about and report on the use of the nuclear reactor as a source of heat. Point out that one of the destructive effects of the atom bomb is the tremendous amount of heat produced.

9. *Effect of heat upon the states of matter* · Place some ice cubes in a Pyrex container and heat the container on a hot plate until the ice cubes melt completely. Then heat the water until it boils. Explain the changes in state in terms of adding heat energy and making the

molecules move faster. Make some ice cubes in the refrigerator and explain the change in state in terms of taking away heat energy and making the molecules move more slowly.

10. *Solids expand when heated and contract when cooled* • Wrap one end of a wire around the head of a nail and attach the other end of the wire to a ringstand (Figure 18–1). Adjust the length of the wire so that the tip of the nail just clears the table top and can swing freely. Now heat the wire with a Bunsen burner or an alcohol lamp, moving the flame up and down the wire. The wire expands so that the tip of the nail touches the table top and the nail can no longer swing freely. Remove the flame and allow the wire to coil. The wire will contract, allowing the tip of the nail to clear the table top again.

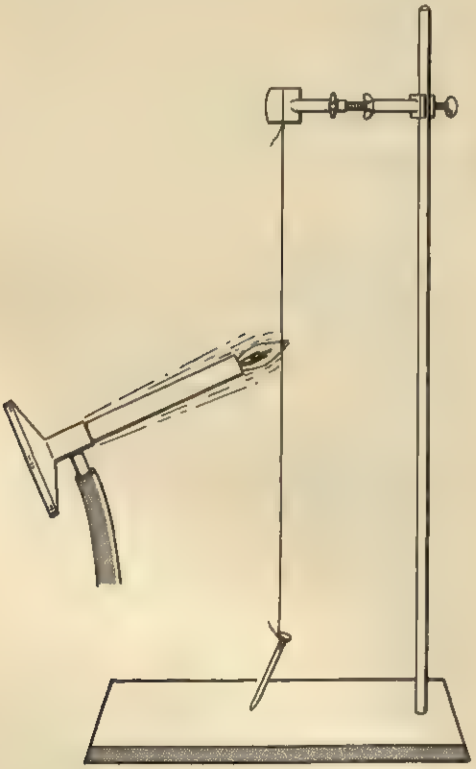


FIGURE 18–1.
THE WIRE EXPANDS WHEN HEATED AND CONTRACTS WHEN COOLED.

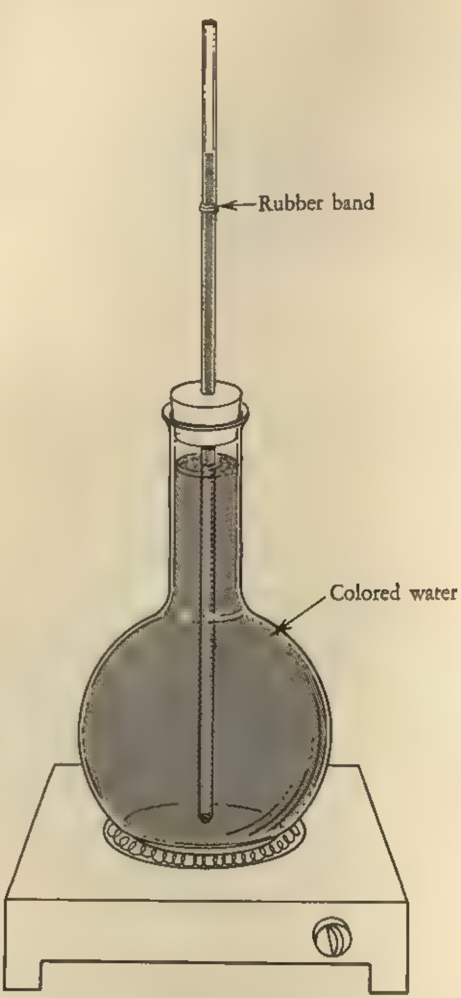


FIGURE 18–2.
THE WATER EXPANDS AND RISES WHEN HEATED AND CONTRACTS AND FALLS WHEN COOLED.

11. *Liquids expand when heated and contract when cooled* • Pour water that has been colored a dark red with food coloring into a Pyrex flask until the flask is almost full. Insert a long glass or plastic tube into a one-hole rubber stopper and fit the stopper tightly into the mouth of the flask. The amount of water in the flask will have to be adjusted so that, when the stopper is inserted, the colored water will rise about one half the distance of the part of the tube above the stopper (Figure 18–2). Place a small rubber band around the

tube at the level of the liquid. Heat the flask on a hot plate just long enough to show the water expanding and rising up the tube. Transfer the flask to a pan of cold water and note that the water contracts and falls down the tube. Point out that both the rate and amount of expansion and contraction is greater for liquids than for solids.

12. *Gases expand when heated and contract when cooled* · Repeat Learning Activity 20 of "Air," Chapter 12 (p. 422). Note that both the rate and amount of expansion and contraction is greatest for gases, as compared with liquids and solids.

13. *The rate of expansion and contraction differs between solids* · Obtain an inexpensive oven or desk thermometer and remove the back. Examine the springlike coil of metal. Point out that two different metals (most likely brass and steel) have been welded together to form a single strip. Heat the coil with a lighted match and note how, as one metal (brass) expands more than the other, the coil twists and makes the pointer move across the scale. Allow the coil to cool, and watch the pointer return to its original position.

14. *Water is an exception to the rule of expansion and contraction* · Fill a plastic bottle full of water and screw the cap on tightly. Allow the bottle to stand overnight in the freezer compartment of a refrigerator. Remove the bottle the next day and note how it bulges because the water expanded when it was cooled below 39 degrees Fahrenheit and then froze.

15. *Rubber is an exception to the rule of expansion and contraction* · Cut one end of a long rubber band. Wrap one end of the rubber band around the head of a nail and attach the other end to a ringstand, as described and pictured in Learning Activity 10 above. Now move a candle flame quickly up and down the rubber band several times, being careful not to hold the flame too close to the rubber band. The rubber band will contract when heated and it will pull up the the nail.

16. *Expansion and contraction in daily life* · Have the children look for and make a list of examples of expansion and contraction that occur or are made use of in our daily life.

TEMPERATURE

1. *Show the principle underlying the operation of liquid thermometers* · Repeat Learning Activity 11 of "The Nature of Heat" (p. 674). Demonstrate a liquid thermometer for comparison, placing your fingers on the bulb to make the liquid in the thermometer rise.

2. *Temperature scales* · Make ribbon thermometers to illustrate temperature scales. Obtain some sturdy white cardboard about 30 inches long and 10 inches wide. Cut ½-inch slits in the center of the cardboard near the top and the bottom (Figure 18–3). Obtain some red ribbon and white ribbon, each about ½ inch wide. Sew one end of the red ribbon neatly and firmly to one end of the white ribbon. Slip the loose ends of the red and white ribbon through the slits as shown in the diagram. Cut off any excess ribbon and sew the other two ribbon ends together. Now by pulling the ribbon at the back, you can make the red ribbon (which represents the mercury or alcohol in a thermometer) rise or fall. Use India ink to mark the distance between both slits into equal divisions to produce an accurate representation of the Fahrenheit scale.

Prepare a second ribbon thermometer illustrating the Centigrade (Celsius) scale. Then prepare a third thermometer showing the Fahrenheit scale on one side of the ribbon and the Centigrade scale on the other side.

Have the children study each scale separately. Let them take readings with actual mercury thermometers of the temperature of the room, hot and cold liquids, etc. Find the boiling point and freezing point of water on each thermometer and scale (using a mixture

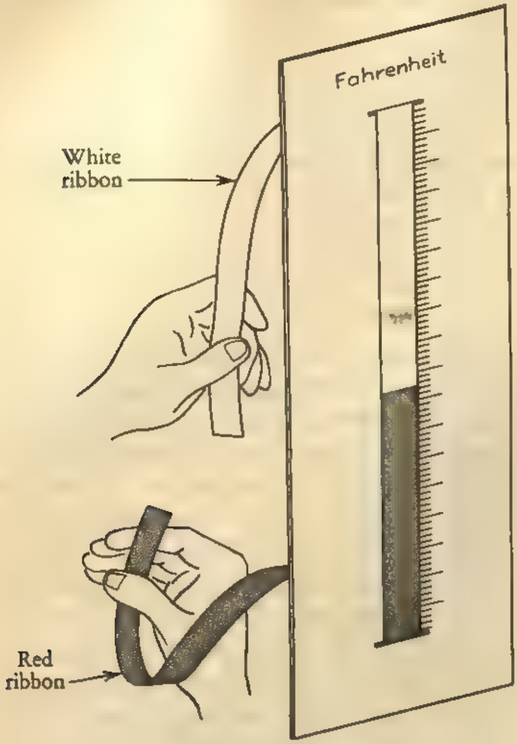


FIGURE 18–3.
A RED AND WHITE RIBBON THERMOMETER.

of ice and water for the freezing point). Point out that the boiling point and freezing point vary, depending upon how much your city or town is above sea level.

After the children have mastered reading each scale separately, show them the ribbon thermometer containing both scales. Compare such fixed points as the boiling and freezing points of water on both scales. Show the children how to convert temperatures from one scale to another, checking the results on the ribbon thermometer.

3. *The clinical thermometer* · Have the children examine a clinical thermometer. Point out the narrow bend that prevents the mercury from falling down the tube, and show how the mercury must be shaken down. Note that the scale is marked in tenths of a degree.

4. *Make an air thermometer* · Obtain a small flask or bottle, a one-hole rubber stopper, and a narrow glass or plastic tube about 18 to 24 inches long. Insert the tube into the stopper and fit the stopper tightly into the neck of the flask. Support the flask with an iron ring attached to a ringstand, as shown in Figure 18–4. Place the end of the tube in a beaker or tumbler of water colored a very deep red with food coloring.

Heat the flask very gently with a small Bunsen burner flame or with an alcohol lamp, moving the flame back and forth along the flask. The heat will cause the air inside the flask to expand, and bubbles of air will leave the bottom of the tube. Drive out enough air so that, when the flame is removed and the air inside the flask cools and contracts, the colored water rises a sizable distance up the tube. Point out that the air pressure on the surface

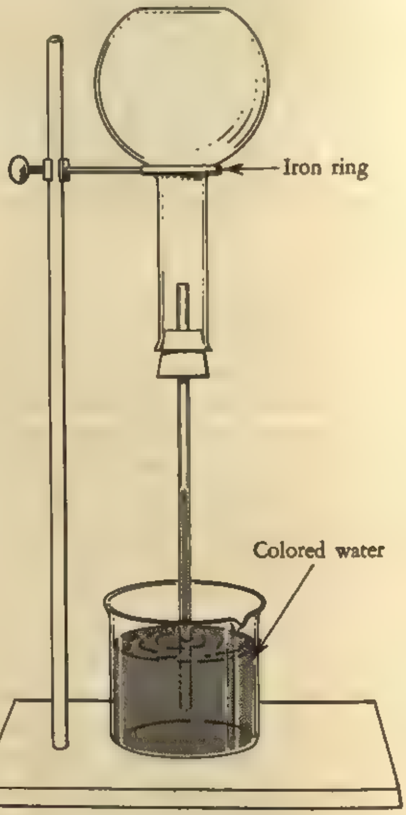


FIGURE 18–4.
AN AIR THERMOMETER WORKS DIFFERENTLY FROM A LIQUID THERMOMETER.

of the colored water forced the water up the tube, taking the place of the air that was driven out of the flask.

Now put your hands in hot water, dry them, and place them around the flask. The colored water will be driven down the tube as the air inside becomes warm and expands. Cool your hands and place them around the flask. This time the colored water will rise up the tube, as the air inside the flask cools and contracts. If you like, prepare a cardboard temperature scale behind the air thermometer and let the children take daily room temperature readings.

5. *Examine a metal thermometer* · Repeat Learning Activity 13 of "The Nature of Heat" (p. 675). Compare the accuracy of a metal thermometer with that of a mercury thermometer.

6. *Use of thermometers* · Have the children make a list of the uses of thermometers at home and by industry.

METHODS OF HEAT TRAVEL

1. *Metals are good conductors of heat* · Place a metal spoon in a cup of very hot water. In a short time the part of the spoon above the surface of the hot water will become hot. Point out that the heat energy has been passed on, or conducted, from molecule to molecule.

2. *Some metals conduct heat better than others* · Into a cup or beaker of very hot water place a sterling silver spoon, a silverplate spoon, and a stainless steel spoon. Note which spoon handle becomes the hottest. Repeat the learning activity, using rods of different materials such as brass, iron, and copper.

3. *Some solids are poor heat conductors* · Into a cup or beaker of very hot water place rods of such materials as wood, glass, and plastic. Use rods of equal length and thickness. Note that the parts above the surface of the water do not become hot, or even warm. Put a piece of rubber tubing in the hot water. The end outside the water will not become hot.

Wrap some cloth around one end of a metal rod and place the other end into the flame of a Bunsen burner or alcohol lamp. Because the cloth is a poor conductor of heat, you will not burn your hand even though the metal rod becomes very hot. Repeat this learning activity, using some thicknesses of paper wrapped around the metal rod.

4. *Water is a poor conductor of heat* · Fill a test tube almost full of cold water and fasten the test tube with a clamp to a ringstand (Figure 18–5). Have the clamp nearer to the bottom of the test tube. Now heat the top of the test tube with the flame of a Bunsen burner or alcohol lamp, moving the flame back and

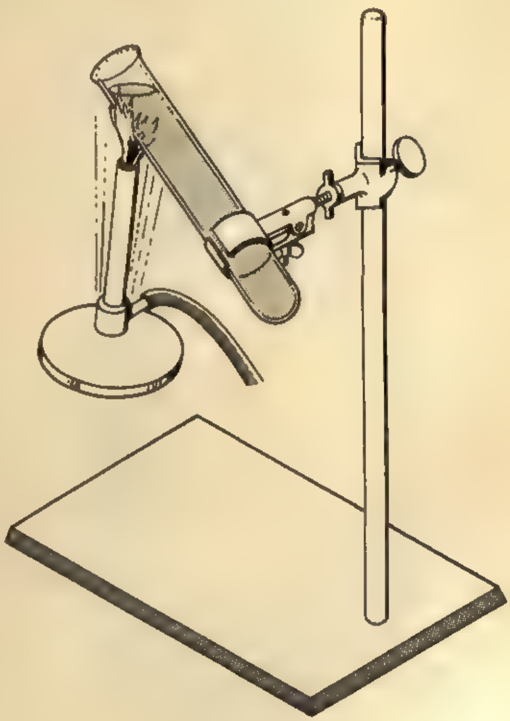


FIGURE 18–5.
THE WATER AT THE TOP OF THE TEST TUBE WILL BOIL WHILE THE WATER AT THE BOTTOM IS STILL COLD.

forth, until the water boils. Feel the bottom of the test tube. The water will still be cold.

5. *Air is a poor conductor of heat* · Hold one end of a short metal rod with your hand and place the other end in the flame of a Bunsen burner or alcohol lamp. In a very short time the end of the rod you are holding will become hot, as the heat travels along the rod by conduction.

Let the metal rod become cool and repeat the learning activity, this time holding the end of the rod with an asbestos mitt. At the same time hold with your bare hand one end of a second short rod about 1 inch away from the end of the first rod (Figure 18–6). The second

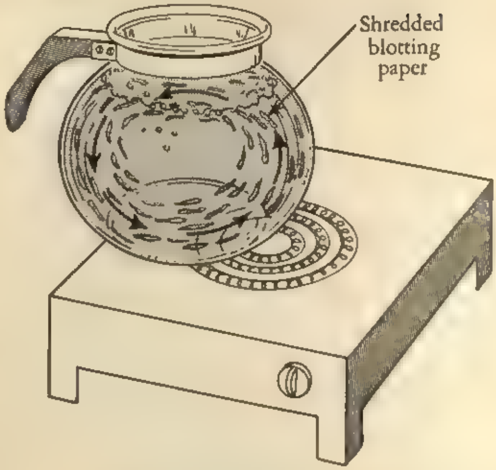


FIGURE 18–7.
A CONVECTION WATER CURRENT.

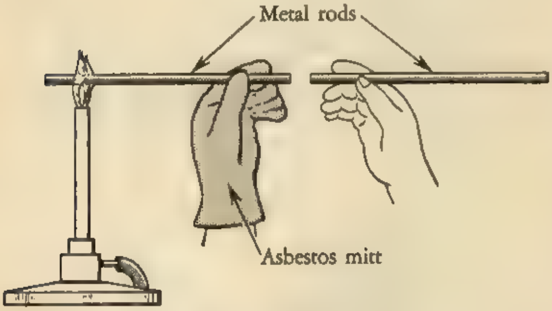


FIGURE 18–6.
BECAUSE AIR IS A POOR HEAT CONDUCTOR, THE SECOND ROD REMAINS COOL.

rod will remain cool because the air between the two rods is a poor conductor of heat.

6. *Heat travels in water by convection* · Fill a large beaker or Pyrex pot almost full of water. Shred a blotter with a food grater and place the fine particles in the water. Muddle the bits of blotting paper until they become thoroughly soaked and sink to the bottom of the beaker. Now place the beaker on one side of a hot plate and heat the beaker (Figure 18–7). The blotting paper will indicate the path of the convection current produced in the water. The bits of blotting paper will move up the side of the beaker resting on the hot coils, and travel down on the cooler side of the beaker.

7. *Heat travels in air by convection* · Repeat Learning Activity 3 of "Winds," Chapter 11 (p. 382). Trace the convection current moving from one lamp chimney through the box to the other chimney.

8. *Heat can travel by radiation* · Turn on an electric clothes iron and place the palm of your hand a few inches below the base of the iron. The heat you feel is radiant energy that was absorbed by your hand and changed into heat. Note that the heat could not have reached your hand by conduction because the air between the iron and your hand is a poor heat conductor, Also, because your hand was below the iron, the heat could not have reached your hand by a rising convection current.

9. *Effect of radiant energy on different materials* · Repeat Learning Activity 2 of "Winds," Chapter 11 (p. 382). Show that radiant energy passes through transparent materials without being changed into heat. Allow sunlight to pass through a glass window and fall on your face. Your face will absorb the sun's radiant energy

and feel warm, but the transparent glass will remain cool.

10. *Heating the home* · Draw diagrams showing the different kinds of heating systems commonly found in the home. Point out the methods of heat travel involved in each case. Discuss the advantages and disadvantages of each system. Have the children read about and report on such newer heating systems as solar heating and the heat pump system.

11. *Insulating the home* · Have the children read about and report on the different ways that heat may be lost in the home and how this heat loss can be prevented. Obtain and examine samples of such insulating materials as rock wool and asbestos. Note how fluffy the material is, containing many air spaces which prevent heat from being conducted away. Wrap some of this insulating material around one end of a short metal rod and place the other end of the rod into the flame of a Bunsen burner or alcohol lamp. The insulating material will now prevent the heat from passing out of the metal rod and into your hand.

12. *Refrigeration and deep freeze* · Have some children read about and report on how refrigerators work. Show that evaporation is a cooling process by moistening a finger and then blowing on it. When the water evaporates, it takes heat from the materials surrounding the water, and cools the materials.

Discuss the effects of slow freezing and quick freezing on foods. Find out the extent to which refrigeration and deep freezing slow down the spoiling of food. Compare the operation of a refrigerator and a freezer.

13. *Air conditioning* · Have the children read about and report on the different functions of an air conditioner, and then describe how each function is accomplished. Ask the children to compare the operation of the cooling unit in an air conditioner with the cooling unit in a refrigerator.

FIRE

1. *Oxidation* · Repeat Learning Activity 4 of "Air," Chapter 12 (p. 418). A simpler alternative would be to wet thoroughly a wad of steel wool and leave it exposed to the air for a day or two. Point out that oxidation has taken place, whereby the iron combined with the oxygen in the air to form iron oxide (rust).

2. *Slow oxidation produces heat* · Soak a wad of steel wool thoroughly in water, remove the wad, allow it to drain, and then stuff the steel wool into a thermos bottle. Obtain a one-hole rubber stopper large enough to fit the mouth of the thermos bottle, and insert a thermometer into the hole. After the steel wool has been in the thermos for about 10 minutes, insert the stopper and the thermometer (Figure 18-8). The temperature will

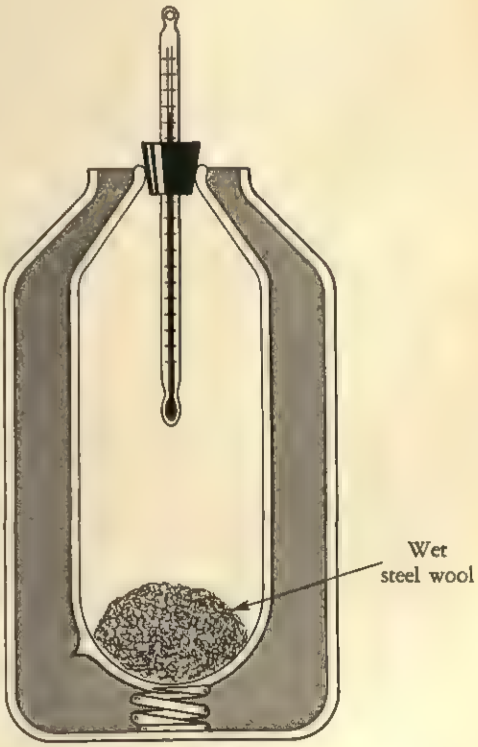


FIGURE 18-8.
WET STEEL WOOL OXIDIZES SLOWLY AND GIVES OFF HEAT.

soon rise, showing that heat is being produced as oxidation takes place. The temperature will stop rising after about 20 minutes because all the oxygen present in the air inside the thermos will be used up. When the temperature has stopped rising, remove the stopper, allow fresh air to enter, and then replace the stopper. The temperature will begin to rise again.

3. *Rapid oxidation produces heat and light* · Show examples of rapid oxidation by lighting a match, burning paper or wood, and operating a cigarette lighter. Point out that in each case the rapid oxidation produced heat and light.

4. *A fire needs oxygen* · Invert a large glass jar over a burning candle. The flame will soon flicker and go out, as the oxygen in the air inside the jar is used up.

5. *The effect of the amount of oxygen on burning* · Prepare some pure oxygen by pouring some hydrogen peroxide into a large tumbler or glass jar. Add about a teaspoon of manganese dioxide and then cover the top of the jar with an index card or piece of cardboard. The hydrogen peroxide will decompose, bubbling vigorously, to produce oxygen. (If manganese dioxide is unavailable, use sodium bicarbonate instead. However, it will now take longer for the peroxide to decompose.)

Untwist one end of a piece of picture wire and hold this untwisted end in a flame until the wire begins to glow. Then quickly insert the glowing wire into the jar of pure oxygen (Figure 18–9). The wire will burn like a Fourth of July sparkler in the pure oxygen

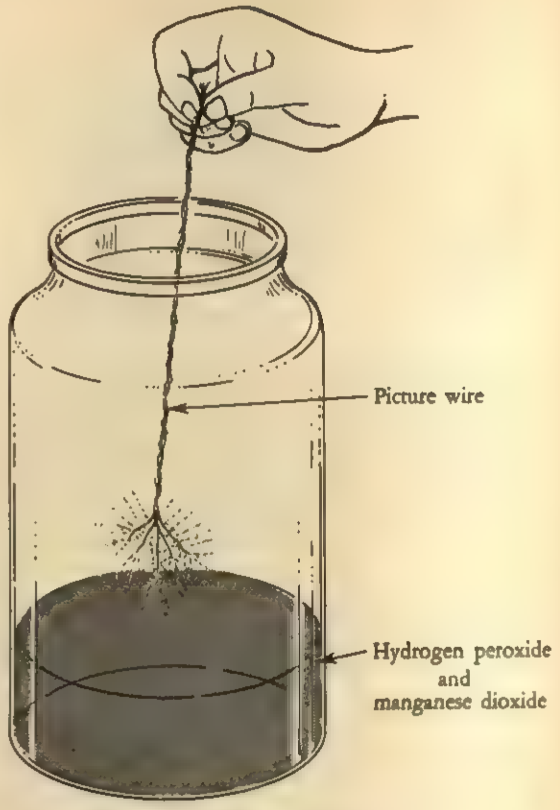


FIGURE 18–9.
PICTURE WIRE BURNS VIGOROUSLY IN PURE OXYGEN.

6. *The effect of surface area on burning* · Repeat Learning Activity 26 of "Machines," Chapter 17 (p. 657). Point out that breaking the alcohol up into small droplets increases the amount of surface area exposed to air, and thus greatly increases the rate of combustion.

7. *Kindling temperature* · Invert a pie tin over a tripod and place a match head on top of the tin (Figure 18–10). Heat the pie tin with a Bunsen burner. When the tin reaches the

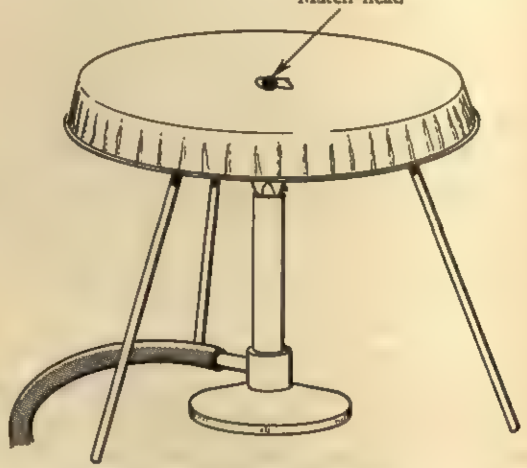


FIGURE 18–10.
A MATCH HEAD HAS A LOW KINDLING TEMPERATURE.

kindling temperature of the match head, the match head will burst into flame.

8. *Materials have different kindling temperatures* · Invert a pie tin over a tripod, as described in Learning Activity 7 above. Place around the edge of the tin a match head, a small amount of sulfur (if available), a piece of paper, a piece of match stick, and a piece of soft coal or charcoal. Have the materials all the same size, and space them equidistant from each other and from the center of the tin. Place a Bunsen burner or alcohol lamp under the center of the tin and light it. Note the order in which the materials reach their kindling temperatures. The match head will burst into flame, followed by the sulfur. The paper will char or burn, and the wood will just char slightly. The coal will not burn because its kindling temperature was not reached.

9. *Flame is burning gas* · Light a candle with a match and allow it to burn for a few minutes. Tilt the candle and note the liquid paraffin that drips down. Point out that when the wick first began to burn, it melted the paraffin, which rose up into the wick and was changed to a gas by the heat of the flame. The gas burns, giving off heat and light.

Snuff out the candle flame with a test tube, then immediately light a match and lower it toward the wick (Figure 18–11). You will light the candle before you touch the wick. Point out that when the candle was snuffed, the wick was still hot and continued to change the liquid paraffin to a gas for a short time. The burning match set fire to this gas, which then set fire to the wick.

10. *The color of a flame depends upon the amount of oxygen available* · Light a Bunsen burner or a propane gas burner. Adjust the barrel so that the gas is getting all the air it needs, burning completely and making the flame blue. Now adjust the barrel so that the gas is getting little or no air, making the flame yellow. Point out that the yellow color is caused by glowing, unburned particles of fuel.

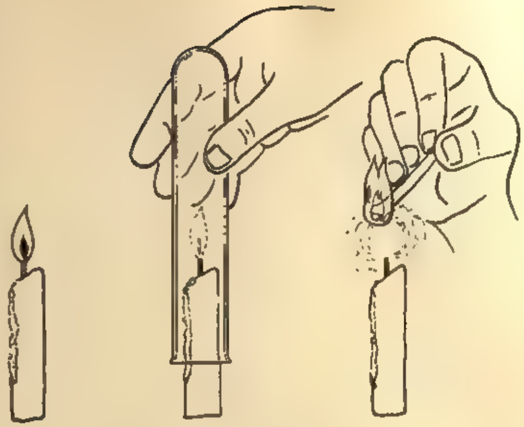


FIGURE 18–11.
A CANDLE IS A MASS OF BURNING GAS.

11. *Examine the parts of a flame* · Light a candle, and then partially darken the room. Examine the candle flame, using a magnifying glass for better observation. Note the dark inner part, the good-sized yellow part, and the small blue part around the edges of the flame. Repeat, using a Bunsen burner flame.

12. *Burning produces carbon dioxide* · Wrap a wire around a burning candle, lower it into a glass jar, and cover the jar with an index card or piece of cardboard (Figure 18–12). When the flame goes out, remove the candle, and pour in some limewater (obtained from the drugstore). Put your hand over the jar and shake it. The limewater will turn milky, showing the presence of carbon dioxide. You can first establish limewater as a test for the presence of carbon dioxide by bubbling your breath through a soda straw into a test tube containing some limewater.

13. *Burning produces water* · Chill a beaker or glass tumbler in the refrigerator, and then hold the beaker upside down over a candle flame. A film of dew or fine moisture will condense on the inside of the beaker.

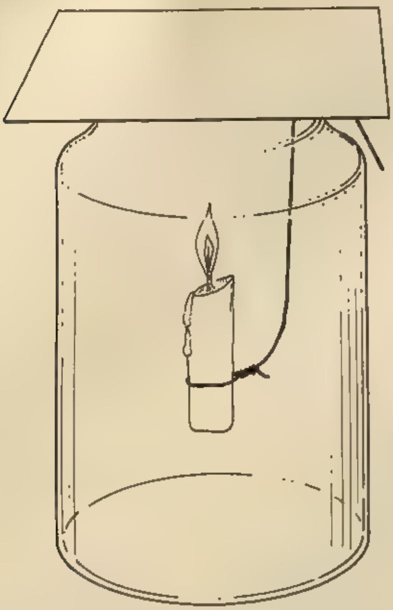


FIGURE 18–12.
A BURNING CANDLE PRODUCES CARBON DIOXIDE.

14. *Smoke and ash* · Burn some rope or damp paper towel and note the smoke produced. Burn a match, piece of paper, or strip of cotton cloth, and examine the ash that is left. Discuss the difference between smoke and ash.

15. *Spontaneous combustion* · Repeat Learning Activity 2 above, using a wad of cotton that has been soaked in boiled linseed oil instead. Point out that continued oxidation would soon produce enough heat to reach the kindling point of the cotton.

16. *Factors necessary to put out fire* · Build a miniature campfire in a large pie tin. Show how the fire can be put out by removing or scattering the fuel, by covering the fire with earth to cut off the supply of oxygen, and by adding water to cool the burning fuel below its kindling temperature.

17. *Carbon dioxide puts out fire* · Obtain three candles of different sizes and place them on a piece of cardboard. Prepare a cardboard trough with three holes, each hole just large enough to fit snugly over the candles. Fit the trough over the candles so that it is just below the top of each candle (Figure 18–13), and then light the candles.

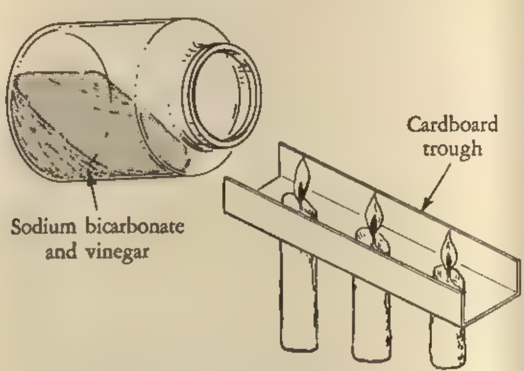


FIGURE 18–13.
CARBON DIOXIDE PUTS OUT THE CANDLE FLAMES.

Obtain a large glass jar or beaker. Prepare carbon dioxide by pouring some baking soda (sodium bicarbonate) into the jar, adding vinegar, and then covering the jar with a piece of cardboard or an index card until the bubbling subsides. Remove the cardboard and tilt the jar over the higher end of the trough, allowing just the invisible carbon dioxide to flow into the trough and put out the candle flames.

18. *Make a foam fire extinguisher* · Put 2 tablespoons of baking soda into a tumbler of water, stir, and then pour into a quart-size glass jar. Break an egg and pour the contents into the jar. Cap the jar and shake the contents thoroughly. Obtain a large pie tin and place it on an asbestos mat. Pour some alcohol or lighter fluid into the tin and set fire to the alcohol with a lighted match (be very careful not to spread the fire). Place the jar in the center of the tin and immediately pour a cup of vinegar into the jar. A foam will form, which will overflow the jar, pour down the sides, and put out the fire. Point out that the egg made it possible for the bubbles of carbon dioxide to cling together and form a foamy mass.

19. *Commercial fire extinguishers* · Have a representative of the fire department demonstrate different kinds of fire extinguishers. Let some children read about and report on how large forest, oil, factory, or home fires are put out.

20. *How fire helps man* · Have the children make a list of the different uses man has for fire.

21. *Safety rules for fires* · Make a list of fire hazards that may exist in the home. Follow with a list of safety rules for preventing fires.

FUELS

1. *Kinds of fuels* · Have the children list, or perhaps even collect and exhibit, different fuels available in the community. Let them describe for each fuel the characteristics that make it a good fuel. Divide the fuels into three groups: solids, liquids, and gases. (It would be wise to exclude gasoline from an exhibit.)

2. *Most fuels contain carbon* · Lower a white porcelain or china dish into a candle flame. Hold the dish in the flame until a good-sized black spot (soot) appears, and then remove the dish. The black spot consists of particles of unburned carbon.

3. *Most fuels contain hydrogen* · Repeat Learning Activity 13 of "Fire" (p. 681). Point out that the hydrogen of the fuel combined with oxygen in the air to form water vapor, which condensed on the cool inside walls of the beaker.

4. *Make charcoal* · Punch a small hole in the cover of a coffee can with a nail. Obtain some soft pine wood and chop or cut it up into small strips or pieces. Place the wood in the coffee can and cover the can tightly with the cover. Heat the can on a hot plate. Smoke and gas will soon come through the nail hole. Wait a short while until all the air has been driven from the can, and then try to light the gas coming through the hole (Figure 18–14). After a few trials, the gas will burn with a flickering flame. Continue heating the can for at least ½ hour, and then remove the can from the hot plate and allow it to cool. Pull off the cover and examine the charcoal that has been formed. Repeat the learning activity, using either small pieces of soft coal or some paper toweling.

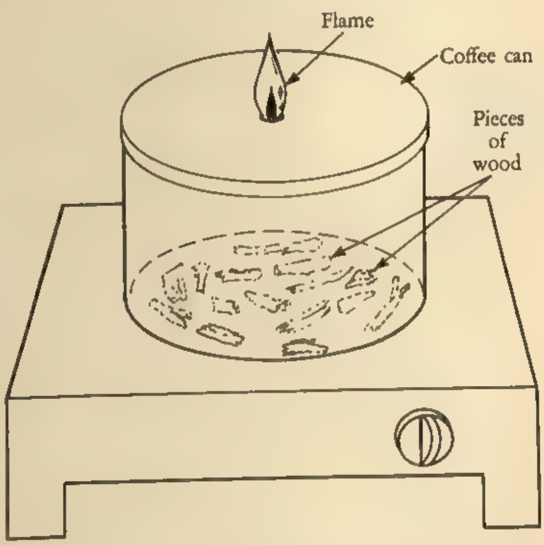


FIGURE 18–14.
HEATING WOOD IN THE ABSENCE OF AIR PRODUCES CHARCOAL.

BIBLIOGRAPHY FOR "HEAT, FIRE, AND FUELS"

ADLER, IRVING. *Fire in Your Life.* New York: Day, 1955. 128 pp.
———. *Hot and Cold.* New York: Day, 1959, 128 pp.
PARKER, BERTHA M. *Fire.* New York: Harper, 1957. 36 pp.
———. *Fire, Friend and Foe.* New York: Harper, 1956. 36 pp.
———. *Heat.* New York: Harper, 1959. 36 pp.
———. *Thermometers, Heat, and Cold.* New York: Harper, 1959. 36 pp.
RUCHLIS, HY. *The Wonder of Heat Energy.* New York: Harper, 1961. 186 pp.

CHAPTER

Sound 19

PRODUCING AND TRANSMITTING SOUND

I. How Sound Is Produced

A. Sound is a form of energy that is caused by an object that is moving back and forth, or vibrating, rapidly.

B. The vibrations can be produced by plucking, stroking, blowing, and hitting.

C. When the vibration stops, the sound stops.

II. How Sounds Travel

A. When an object, such as a violin string or a tuning fork, is made to vibrate, the sound travels out as waves in all directions.

1. When the string vibrates, it moves back and forth very rapidly.
2. As it moves forward, it pushes against the molecules of air in front of it and presses them closer together.
3. The space where the molecules are pressed closer together is called a **compression.**
4. As the string moves backward, it leaves behind a space with fewer molecules in it, and these molecules spread farther apart.
5. The space where the molecules are spread farther apart is called a **rarefaction.**
6. One compression and one rarefaction together make up one complete vibration, or sound wave.
7. As the object vibrates back and forth, it produces compressions and rarefactions, one after the other.
8. The presence of compressions and rarefactions means that the molecules of air have been made to move back and forth, or vibrate, too.
9. As the molecules of air vibrate, they bump into other molecules and make these molecules vibrate, which then make still other molecules vibrate.
10. No single molecule travels very far. Each moves back and forth, pushing against other molecules, as the sound waves travel out in all directions.

B. When sound waves, or vibrations, reach the ear, they are carried by the auditory nerve to the brain, which gives us the sensation of sound.

III. Sounds Travel Through Solids, Liquids, and Gases

A. Most sounds come to us through the air, which is a gas.

1. High up on a mountain the air is not as heavy and does not contain as many molecules as the air in a valley, so sound does not travel as fast or as well high up in the air.
2. Sounds travel faster and better in heavy gases, where the molecules are closer

together, than in light gases, where the molecules are farther apart.

3. The speed of sound in air is about 1100 feet a second, or about a mile in 5 seconds.
4. The warmer the air, the faster the molecules move, and the greater the speed of sound will be.
5. The speed of sound in air increases about 1 foot a second for every degree rise in Fahrenheit temperature and about 2 feet a second for every degree rise in Centigrade temperature.

B. Sound travels faster and better through liquids, like water, than through gases.

1. In liquids the molecules are closer together and carry the vibrations more easily and quickly.
2. Sound travels about 4800 feet a second in water, or about four times as fast as in air.

C. Sound travels faster and better through hard solids than through liquids or gases.

1. In these solids the molecules are very close together and carry the vibrations very easily and quickly.
2. Sound travels more than 10,000 feet a second in wood, or about nine times as fast as in air.
3. Sound travels about 16,500 feet a second in steel, or fifteen times as fast as in air.

D. Sound does not travel at all in a vacuum, where there are no molecules to carry the sound waves, or vibrations.

IV. Characteristics of Sound

A. Sounds can differ in three ways: in **pitch**, in **intensity**, and in **quality**.

B. Pitch is the highness or lowness of a sound.

1. When a body is vibrating, it produces a certain number of vibrations, or sound waves, a second.
2. The number of vibrations a body produces a second is called the **frequency**.
3. The faster a body vibrates, the more vibrations it produces a second, and the higher the sound, or pitch.
4. The slower a body vibrates, the less vibrations it produces a second, and the lower the sound, or pitch.
5. The normal human ear can hear sounds with a frequency that ranges between 20 and 20,000 vibrations a second.
6. Dogs are able to hear sounds with a frequency of more than 20,000 vibrations a second.
7. Very high frequency sound waves are called **ultrasonic** sound waves.
8. Ultrasonic sound waves can kill insects and pests, control and operate automatic garage doors, and clean clothes by shaking the dirt out of them.

C. Intensity is the loudness or softness of a sound.

1. The loudness or softness of a sound depends upon how strongly the object is vibrating.
2. The stronger the object vibrates, the more energy the sound wave has, and the greater the size of the sound wave will be.
3. The more energy we put into making a sound, the larger the sound wave we produce, and the louder the sound wave will be.
4. Another way of making sounds louder is to make more air vibrate to produce larger sound waves.
5. Putting the base of a vibrating tuning fork against a table or chalkboard will make the table and chalkboard vibrate also, which will then make the large amount of air around them vibrate as well.
6. The farther sound waves travel, the softer the sound becomes because, as the waves move away from the source of the sound, they become smaller and do not have as much energy.
7. The unit of measurement of the intensity of sound is called the **decibel**, and is measured by a machine called the **sound-level meter.**
8. Whispering produces 10 to 20 decibels of sound; talking rather loudly, 60

decibels; heavy traffic noises, 70 to 80 decibels; and thunder, 110 decibels.

D. The quality of a sound is what helps us tell the difference between different musical instruments, or between persons that are producing the same sound.
   1. Even though the sounds have the same pitch and intensity, they will sound differently.
   2. This difference occurs because, when an object vibrates, it can vibrate as a whole and in parts at the same time.
   3. When this multiple vibration takes place, sounds of different frequencies are heard at the same time.
   4. Each frequency produces a sound of a different pitch.
   5. The lowest sound that the vibrating body produces is called the **fundamental tone.**
   6. The other sounds, having different frequencies, that the vibrating body produces are called **overtones.**
   7. The quality of a sound depends upon the number and strength of the different overtones that are produced.
   8. The quality also depends upon the size, shape, and material of the vibrating object because these variations help decide how many overtones will be produced.

V. Echoes

A. An **echo** is a sound wave that bounces back, or is reflected, from a large hard surface like a cliff or wall of a building.

B. To hear an echo we must be at least 55 feet away from the reflecting surface.
   1. If we are less than 55 feet away, the sound wave bounces back fast enough to join or blend with the original sound and helps make the sound louder.
   2. If we are more than 55 feet away, the sound wave bounces back too late to join the original sound, and the echo now interferes with the new sounds that are being produced.
   3. The farther away the reflecting surface is, the longer time it will take for us to hear the echo.
   4. Sometimes the sound wave bounces off many surfaces and produces a series of echoes.

C. There are many ways that can be used to eliminate annoying echoes in a large room or auditorium.
   1. Soft drapes on walls and window frames, and also rugs on the floor, will absorb the sound waves.
   2. Covering the ceilings, and also the walls, with rough materials or materials that have many little holes in them will break up the sound waves so that very few are reflected back.
   3. Even the persons in the auditorium will help absorb some of the sound waves.

VI. The Voice

A. At the top of the **windpipe,** or **trachea,** in your throat is the **voice box,** or **larynx.**

B. Stretched over the top of the voice box are two thin but strong bands of tissue called the **vocal cords.**

C. When air from the lungs is blown through a narrow slit (the **glottis**) between these two cords, the cords are made to vibrate by the moving air, and sound is produced.
   1. Muscles attached to the vocal cords make the cords tight or loose, and in this way control the pitch of your voice.
   2. The tighter the vocal cords, the faster they vibrate, and the higher the pitch will be.
   3. The greater the force with which the air is blown between the vocal cords, the louder the sound that will be produced.

D. Men's vocal cords are longer and thicker than those of women, so they do not vibrate as fast.
   1. This difference explains why men have lower or deeper voices than women.
   2. A boy's vocal cords get longer and thicker as he gets older, so his voice changes from a high pitch to a low pitch.

E. The quality of your voice depends upon the kind of vocal cords you have.
   1. The air passages in your throat, mouth, and nose, as well as the sinuses in your head, affect the quality of your voice.
   2. The position of your lips, tongue, and teeth play an important part in the kind and quality of sounds you produce.

MUSIC AND MUSICAL INSTRUMENTS

I. Music Versus Noise

A. Pleasant sounds that are produced by regular vibrations are called **music.**

B. Harsh or unpleasant sounds that are produced by irregular vibrations are called **noise.**

II. Musical Instruments

A. **Musical instruments** are devices used to produce pleasant sounds of different pitch, intensity, and quality.

B. Musical instruments are divided into three classes: **stringed instruments, wind instruments,** and **percussion instruments.**

III. Stringed Instruments

A. Stringed instruments contain one or more strings that are made to vibrate and produce musical sounds.

B. The strings are made to vibrate in different ways.
   1. Some strings are stroked or rubbed with a bow, as in the violin, cello, and bass viol.
   2. Some strings are plucked, either with the fingers or with a pick, as in the ukulele, guitar, banjo, and harp.
   3. In the piano, which is also called a percussion instrument, the strings are struck by small hammers.

C. The pitch, or frequency, of all the musical sounds that are produced by stringed instruments can be changed in three different ways.
   1. The looser the string, the lower the pitch; the tighter the string, the higher the pitch.
   2. The longer the string, the lower the pitch; the shorter the string, the higher the pitch.
   3. The thicker the string, the lower the pitch; the thinner the string, the higher the pitch.

D. Stringed instruments like the violin, cello, bass viol, and banjo have just a few strings that are attached to pegs.
   1. The strings are of different thicknesses that produce sounds of higher or lower pitch.
   2. The pegs can be used to tighten or loosen the strings, and make the pitch higher or lower, too.
   3. When these instruments are played, the fingers move up and down the vibrating strings, making them longer and shorter, thus producing lower and higher musical sounds.

E. Stringed instruments like the harp and piano have a great many strings.
   1. The strings all differ in length, thickness, and tightness so that they all produce sounds of different pitch.
   2. The harp also has pedals that can pull the strings tighter and make them produce sounds with a higher pitch.

F. Sounds from stringed instruments can be made louder or softer.
   1. The harder a string is bowed or plucked, the more strongly it vibrates, and the louder the sound that is produced.
   2. The more gently a string is bowed or plucked, the weaker it vibrates, and the softer the sound that is produced.

3. Also, when a string vibrates, it makes the entire instrument vibrate at the same frequency, or pitch.
4. The vibrating instrument makes the air all around the instrument vibrate at the same frequency as well.
5. The large amount of vibrating air reinforces the original vibrations of the string and makes them stronger, which means the sound will be louder.
6. In the piano, a sounding board above the strings vibrates instead of the entire piano.
7. Some instruments, like the violin and the guitar, have holes in them.
8. Not only does the instrument vibrate, but also sound waves go inside the instrument and make the air inside it vibrate at the same pitch, or frequency.
9. The vibrating air joins and reinforces the original vibrations, making them stronger and producing a louder sound.
10. Reinforcement of the original vibrations to make the sound louder is called **resonance.**

G. The sounds from stringed instruments differ in quality.

1. When a string vibrates, the whole string vibrates.
2. The tone produced is called the **fundamental tone.**
3. A vibrating string cannot only vibrate as a whole, but it can also vibrate in parts at the same time.
4. When a string vibrates in two parts, it is just as if two shorter strings were vibrating, with each part just half as long as the original string.
5. These shorter strings vibrate twice as fast, producing a tone one octave higher, called an **overtone.**
6. When a string vibrates in three parts, the parts vibrate three times as fast, producing overtones that are two octaves higher.
7. Vibrating as a whole, the string produces its fundamental tone, which is the lowest tone it can produce.
8. Vibrating in parts, the string produces overtones, which are higher than the fundamental tone.
9. The quality of the sound depends upon the number and strength of the overtones that are produced.
10. The quality also depends upon the size, shape, and material of the instrument because these factors help decide how many overtones will be produced.

IV. Wind Instruments

A. Wind instruments contain a column of air that can be made to vibrate and produce musical sounds.

B. The air column can be made to vibrate by either blowing into it, as is done with the clarinet, saxophone, and trumpet, or by blowing across it, as is done with the flute and piccolo.

C. Wind instruments are divided into two main classes: **woodwind** and **brass instruments.**

D. In all woodwind instruments, except the flute and piccolo, a thin piece of wood or metal, called a **reed,** is used to make the air column vibrate.

1. The reed is in the mouthpiece of the instrument.
2. Blowing into the mouthpiece makes the reed vibrate, which then makes the air column vibrate.
3. In the flute and piccolo, we blow across a hole and start the air column vibrating.
4. Examples of woodwind instruments include the flute, piccolo, clarinet, oboe, bassoon, and English horn.
5. The saxophone uses a reed, but is made of brass, so it belongs partly to the woodwind family and partly to the brass family.

E. All brass instruments are made of brass, and are played by vibrating the lips while they are pressed against the mouthpiece of the instrument.

1. The vibration of the lips starts the air column vibrating.

2. Examples of brass instruments include the trumpet, cornet, bugle, trombone, French horn, and tuba.

F. The pitch or frequency of the vibrating air column can be changed by making the air column longer or shorter.
1. The longer the air column, the lower the pitch; the shorter the air column, the higher the pitch.
2. Woodwind instruments have holes in them, usually covered by pads called keys.
3. Pressing or releasing the keys will open and close the holes, making the length of the air column inside the instrument longer or shorter.
4. Some brass instruments, like the trumpet and the tuba, have valves which are used to control the length of the air column.
5. The trombone has a slide that moves in and out to control the length of the air column.
6. There is no way to change the length of the air column in the bugle, so the different notes are produced by changing both the tightness of the lips and the force of the breath blowing into the instrument.
7. Many wind instruments, especially brass instruments with valves or a slide, also depend on the tightness of the lips and the force of the breath to produce notes of different pitch.

G. Sounds from wind instruments differ in quality.
1. An air column not only vibrates as a whole, but it also vibrates in parts at the same time.
2. Vibrating as a whole, the air column produces its fundamental tone, which is the lowest tone it can produce.
3. Vibrating in parts, the air column produces overtones, which are higher than the fundamental tone.
4. The quality of the sound depends upon the number and strength of overtones produced.
5. The quality also depends upon the size, shape, and material of the instrument because these factors help decide how many overtones will be produced.

H. Blowing harder into the wind instrument will make the air column inside the instrument vibrate more strongly and produce a louder sound.
1. At the same time, the air column vibrates in parts.
2. These new vibrations join and reinforce the original vibrations produced by the air column vibrating as a whole.
3. This combination of vibrations makes the air column vibrate more strongly and produces a louder sound.
4. This reinforcement of the original vibrations to make the sound louder is called **resonance**.
5. In most wind instruments, blowing harder can make the sound not only louder but higher as well.
6. Blowing harder cuts out the fundamental tone so that only the higher overtones are heard.

V. Percussion Instruments

A. Percussion instruments are either made of solid materials, like wood and metal, or else they are made of materials stretched over a hollow container.
1. The solid or stretched materials are struck by a mallet or hammer that makes the materials vibrate and produce sounds.
2. Percussion instruments made of solid materials include the xylophone, glockenspiel, triangle, cymbals, chimes, bells, castanets, and wood block.
3. Percussion instruments made of materials stretched over a hollow container include the bongo drum, snare drum, bass drum, kettle drum, and tambourine.

B. For percussion instruments made of solid materials, the longer the material, the lower the pitch; the shorter the material, the higher the pitch.

C. For percussion instruments made of mate-

rials stretched over a hollow container, the pitch can be changed in different ways.

1. The tighter the covering, the higher the pitch; the looser the covering, the lower the pitch.
2. The thinner the covering, the higher the pitch; the thicker the covering, the lower the pitch.
3. The smaller the covering, the higher the pitch; the larger the covering, the lower the pitch.

D. Striking the percussion instruments harder will make them vibrate more strongly and produce louder sounds.

1. At the same time the vibrating materials make the air around them vibrate at the same frequency.
2. The large amount of vibrating air reinforces the original vibrations and makes them stronger, producing louder sounds.
3. The hollow containers of percussion instruments like the drum, the marimba, and the chimes also help produce louder sounds.
4. The column of air inside the container is made to vibrate at the same frequency as the original sound, reinforcing the original vibrations and making them much stronger, thus producing a louder sound.
5. The vibrating column of air also affects the quality of the sound produced by the percussion instrument.

LEARNING ACTIVITIES FOR "SOUND"

PRODUCING AND TRANSMITTING SOUND

1. *Sound is produced by a vibrating object* · Hold one end of a rubber band in your teeth and stretch the band. Pluck the band in the middle, noting the vibration and the sound produced. The vibration is so rapid that it produces a blur. Note that when the vibration stops, the sound stops. Set a tuning fork vibrating by striking one prong sharply against your kneecap or the rubber heel of your shoe. (Never strike a tuning fork against a hard object.) To show that the tuning fork is vibrating, hold one end of a sheet of paper and touch one prong lightly to the other end of the paper. The vibrating prong will make the paper rattle.

Have the children feel the vibrations by touching the vibrating prongs lightly with their fingertips. Let them place tissue paper against the teeth of a comb and hum a tune. They will feel the vibrations as a ticklish sensation on their lips.

2. *Sound travels in waves* · Pour some water into a tub or large basin. Dip your finger quickly into the water and then pull it out, noting that waves are produced and spread out in concentric circles. Point out that sound waves themselves are not like water waves, but their method of travel is somewhat alike.

3. *Sound travels in all directions* · Place children in four corners of the room, facing the wall. Then have one child stand in the middle of the room and produce a sound. Let the children raise their hands as soon as they hear the sound. Now place one child at the top of the stairs, a second child half-way down, and a third child at the foot of the stairs. Have the child half-way down the stairs make a sound. The sound will travel up and down, as well as in all horizontal directions.

Fill a large beaker or tumbler full of water. Strike the prongs of a tuning fork very sharply against your kneecap or the rubber heel of your shoe, and then quickly place the ends of the

FIGURE 19–1.
THE VIBRATING TUNING FORK SCATTERS WATER IN ALL DIRECTIONS.

prongs in the center of the water (Figure 19–1). The vibrating prongs will make the water splash out of the beaker in all directions.

4. *Sound travels by means of condensation and rarefaction of molecules* · Obtain a "Slinky" (a walking spring coil) from the toy store. Attach one end of the Slinky to a hook high off the floor and allow the rest of the Slinky to stretch to the floor (Figure 19–2). Now press together two of the stretched coils close to the floor, and then release these coils suddenly. An impulse, consisting of a series of condensations and rarefactions, will travel the length of the Slinky. Compare this movement with the way sound travels by means of condensations and rarefactions of molecules. Point out that each coil (and molecule) moves back and forth just a little, yet the result is an extensive movement and travel of the impulse.

5. *Sound travels through solids* · Stand at one end of a table and have a child stand at the other end. Scratch the table top so lightly with your fingernail that the child cannot hear the sound. Now have the child place one ear against the end of the table, and then scratch the table top again. The child will hear the scratching sound very clearly.

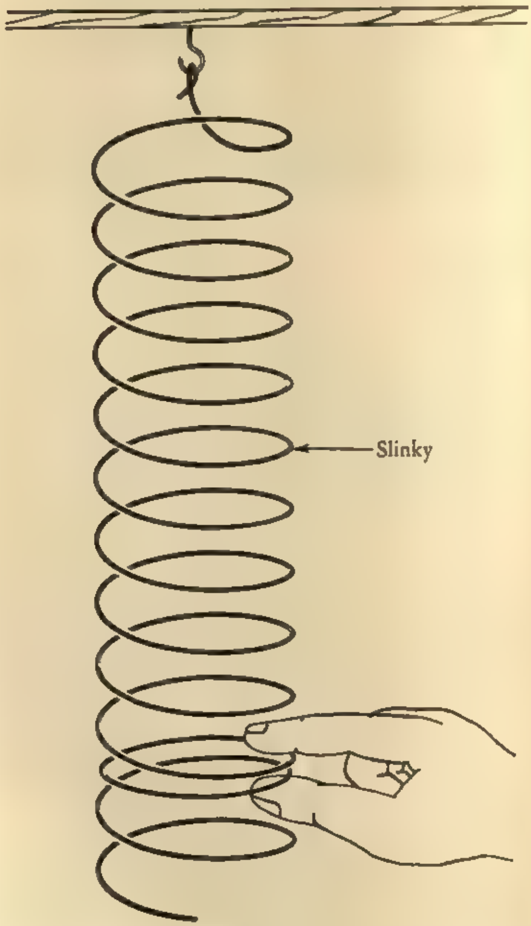


FIGURE 19–2.
A "SLINKY" SHOWS HOW SOUND TRAVELS BY CONDENSATION AND RAREFACTION OF MOLECULES.

Repeat Learning Activity 7 of "The Circulatory System," Chapter 15 (p. 591) to show how the use of the stethoscope illustrates that sounds travel through solids.

6. *Sound travels through liquids* · Fill a large aquarium almost full of water. Pound two rocks together about 6 to 8 inches from a child's ear. Now have the child place his ear against one end of the aquarium. Pound the rocks together again, this time under the water in the aquarium. The child will hear the sound, but it will be much louder.

7. *Sound travels through gases* · Obtain a garden hose that is 50 feet long. Send one child out of the room with one end of the garden hose, and have another child speak very softly into the other end of the hose. The child outside the room will be able to hear the words very clearly.

8. *Sound does not travel through a vacuum* · Obtain a large Pyrex flask and a solid rubber stopper that fits the mouth of the flask. Push a small hook into the underside of the stopper. From the hook suspend a string that is attached to a small jingle bell so that the bell will hang freely inside the flask when the stopper is inserted (Figure 19–3). Place a small amount of water in the flask, set the flask on a hot plate, and boil the water until almost all the air inside the flask has been driven off and there is mostly steam inside the flask. Remove the flask, insert the stopper, and allow the flask to cool. The steam will condense, leaving a partial vacuum in the flask.

Set up a second (control) flask exactly like the first, but do not boil the water so that this second flask is full of air. Now shake both flasks gently. Compare the loudness of the bell in the partial vacuum with that of the bell in air.

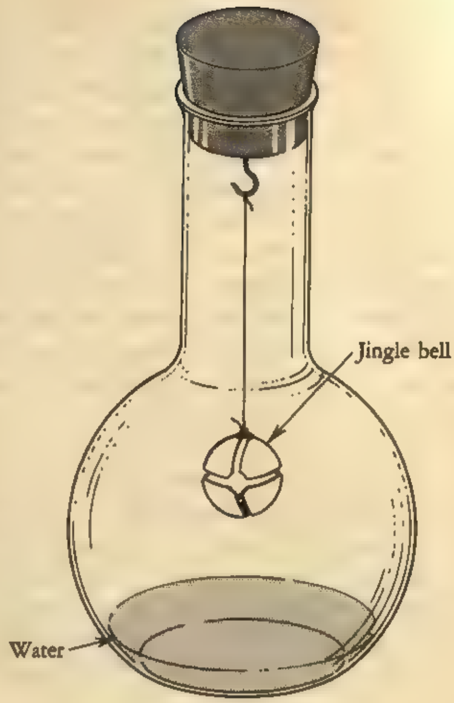


FIGURE 19–3.
THE SOUND OF THE BELL CANNOT BE HEARD IN A VACUUM.

9. *The speed of sound* · Have the children read about and report on the speed of sound in air, water, and solids like wood and steel. Discuss the effect of temperature on the speed of sound, pointing out that heat produces an increase in molecular motion.

Ask the children to watch a jet plane as it is traveling. The sound of the plane will seem to be coming from a point in the sky way behind the spot where they see the plane. Point out that light travels so much faster than sound that they see the plane immediately. It takes more time for the sound to reach their ears.

10. *Pitch* · Draw the edge of an index card over the teeth of a comb at different speeds. The faster the index card moves against the teeth, the faster it vibrates, and the higher the sound becomes.

11. *Ultrasonic sound waves* · Blow a dog whistle. Point out that our ears can only hear sounds within a definite frequency range. Have the children read about and report on the uses of ultrasonic sound waves.

12. *Intensity* · Repeat Learning Activity 1 above, producing soft and loud sounds by varying the intensity with which you pluck the rubber band, strike the tuning fork, and hum against the tissue paper. Place an alarm clock at one end of the room. Have the children listen to the ticking at different distances from the clock, and note that the intensity of the sound decreases as the distance from the source of the sound increases.

Have the children read about and report on measuring the intensity of sound, and have them find out the number of decibels produced by a variety of common sounds.

13. *Quality* · Push a table against the wall. Attach an electric bulb to a piece of wood and bend the clapper of the bell so that it will not strike the gong when it is moving back and forth. Connect the bell to two dry cells and a switch, as shown in Figure 19–4. Obtain about

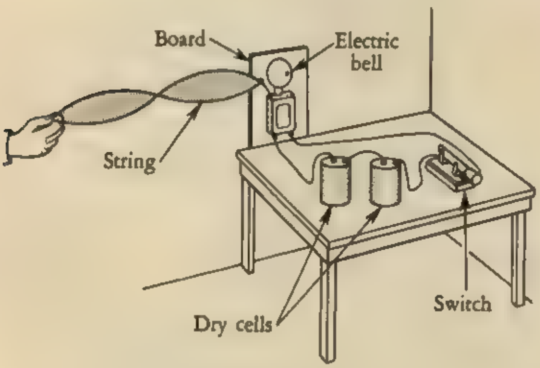


FIGURE 19–4.
FORMING LOOPS TO ILLUSTRATE FUNDAMENTAL TONE AND OVERTONES.

10 feet of thin, soft string and attach one end of the string to the clapper. Push down the switch to complete the electric circuit and set the clapper moving back and forth.

Stand some distance away and pull on the string as the clapper vibrates. By experimenting with the amount of pull on the string, you will be able to make the string vibrate as a whole to form just one loop, and then vibrate in parts to form two, three, or even four loops. Compare this formation of loops with the formation of the fundamental tone and overtones in vibrating objects to produce sounds of different quality.

14. *Echo* · Bring the children to the school auditorium or gymnasium when it is empty. Stand at one end of the auditorium and produce echoes. Have the children recall that these echoes are not heard when the auditorium is filled. The sounds are absorbed by the persons in the auditorium.

Discuss the use of such materials as drapes, curtains, carpeting, acoustical ceiling tiles, and foam rubber padding to absorb sound waves and eliminate echoes. Lower a ringing alarm clock about half-way down into a closed cardboard carton and note the loudness of the sound. Now tape the inside of the carton with foam rubber or thicknesses of cloth. Lower the ringing alarm clock again into the carton and note how much softer the sound becomes.

15. *The voice* · Have the children feel their windpipes while they are humming or making low sounds. They will feel the vibrations of their vocal cords. Have them make loud and soft sounds, noting the greater force with which air is blown between the vocal cords to produce louder sounds. Let one child say something normally, and then repeat it while pinching his nostrils shut. Note the change in quality of the sounds produced.

Inflate a balloon and allow the air to escape while you pinch and stretch both sides of the neck of the balloon. The more you pinch and stretch the rubber, the higher the sound becomes. Compare this effect with the tightening of the vocal cords to produce higher sounds. Discuss the difference in length and thickness of men's and women's vocal cords, and the effect on the pitch of the sounds produced.

16. *Sounds and hearing* · Repeat Learning Activities 13 and 14 of "The Sense Organs," Chapter 15 (p. 597) and trace the relationship between sounds, the ear, and hearing.

MUSIC AND MUSICAL INSTRUMENTS

1. *Music and noise* · Have the children make a list of unpleasant noises they have heard. Relate noise with irregular vibrations and music with regular vibrations. Draw diagrams of both regular and irregular vibrations on the chalkboard (Figure 19–5).

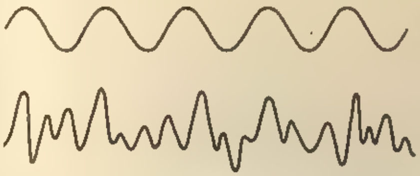


FIGURE 19–5.
DIAGRAMS SHOWING THE DIFFERENCE BETWEEN MUSIC AND NOISE.

2. *Producing sounds in musical instruments* · Obtain and/or have the children bring in a variety of musical instruments, making sure you have adequate representation of stringed, wind, and percussion instruments. For each instrument show how sounds are produced, made higher or lower, and louder or softer. Have the children produce sounds of the same pitch and intensity from different instruments, and note the difference in the quality of the sounds. Discuss the formation of overtones in each instrument and their relationship to the quality of the musical sounds produced.

3. *Forced vibrations increase the intensity of musical sounds* · Strike a tuning fork, hold it upright, and have the children listen to the sound produced. Strike the tuning fork again, but this time touch the handle of the tuning fork to a table top or the chalkboard. The vibrating tuning fork will force the table top to vibrate with the same frequency, and the vibrating table top will now force the air around it to vibrate with the same frequency too. This large amount of vibrating air reinforces the original vibrations of the tuning fork, making them stronger so that the sound becomes louder. Show how this same effect is produced with musical instruments.

4. *Changing the pitch in stringed instruments* · Obtain a cigar box, remove the cover, and cut three grooves on each edge of the box. Obtain three rubber bands of equal length but different thicknesses and stretch them lengthwise around the box, placing them in the grooves to keep them in place (Figure 19–6).

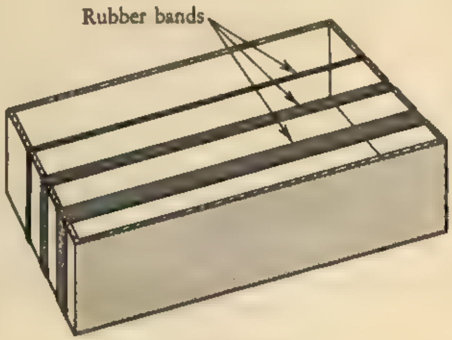


FIGURE 19–6.
A STRINGED INSTRUMENT MADE FROM A CIGAR BOX.

Pluck each band and note that the thinner the band, the higher the sound will be.

Pluck one band and note the sound produced. Hold the middle of the band with your fingers and pluck either portion of the band that extends from your fingers to one edge of the box. Note that only half of the rubber band now vibrates and the sound is higher. In fact, the sound is now twice as high as the original sound. Hold the band at different positions. The shorter the length of the vibrating band, the higher the sound will be.

Pluck one rubber band and listen to the note produced. Now pull the band at one end, making it tighter. Note that the tighter the band becomes, the higher the sound will be.

Use real stringed instruments to show how

thickness, length, and tension are used to produce sounds of different pitch.

5. *Changing the pitch in wind instruments* · Blow across the mouth of an empty soda pop bottle. The sound is produced by the column of vibrating air inside the bottle. Repeat the activity, using bottles of different sizes. The smaller the bottle, the shorter the air column will be, and the higher the sound will become.

Obtain eight soda pop bottles all the same size and line them up in a row. Pour different amounts of water in them, adding or taking away water as needed, until you have produced the eight notes of the scale when you blow across their mouths (Figure 19–7). Note

FIGURE 19–7.
PRODUCING AIR COLUMNS OF DIFFERENT SIZES IN SODA POP BOTTLES.

the relationship between the length of the air column in each bottle and the pitch of the sound produced.

Use real wind instruments to show how changing the length of the vibrating air columns will produce sounds of different pitch.

6. *Changing the pitch of percussion instruments* · Use a toy xylophone to show that the shorter the bar, the higher the sound will become. Cut a piece of rubber from a large balloon or an old inner tube and place it over the mouth of a glass jar. Grasp the rubber with both hands and pull it downward while a child strikes the rubber repeatedly with the eraser part of a pencil (Figure 19–8). Note that the tighter the rubber drum head becomes as it is pulled further downward, the higher the sound will become. Repeat this activity with jars of the same size, but having mouths

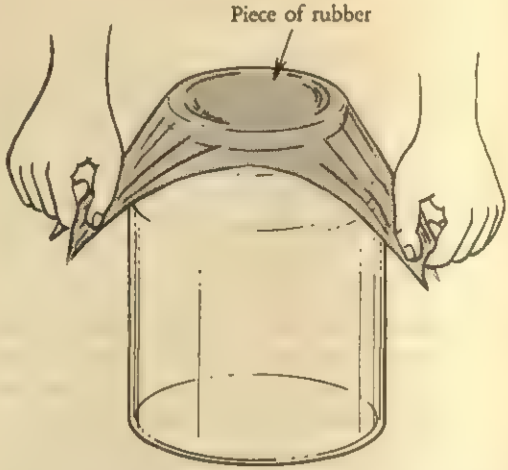


FIGURE 19–8.
THE TIGHTER THE DRUM HEAD, THE HIGHER THE SOUND WILL BECOME.

of different widths. The narrower the mouth of the jar, the higher the sound that is produced. Using rubber pieces of different thicknesses over the mouth of the jar will show that the thinner the rubber, the higher the sound that is produced.

BIBLIOGRAPHY FOR "SOUND"

ANDERSON, DOROTHY S. *Junior Science Book of Sound.* Scarsdale, N.Y.: Garrard, 1962. 63 pp.

BERGER, MELVIN, and FRANK CLARK. *Science and Music.* New York: McGraw, 1961. 176 pp.

FERAVALO, ROCCO. *Wonders of Sound.* New York: Dodd, 1962. 54 pp.

FREEMAN, IRA M. *All About Sound and Ultrasonics.* New York: Random, 1961. 138 pp.

IRVING, ROBERT (pseud. of Irving Adler). *Sound and Ultrasonics.* New York: Knopf, 1959. 146 pp.

KETTELKAMP, LARRY. *Drums, Rattles, and Bells.* New York: Morrow, 1960. 48 pp.

KNIGHT, DAVID C. *The First Book of Sound.* New York: Watts, 1960. 93 pp.

NEAL, CHARLES D. *Sound.* Chicago: Follett, 1962. 32 pp.

PARKER, BERTHA M. *Sound.* New York: Harper, 1959. 36 pp.

PINE, TILLIE S., and JOSEPH LEVINE. *Sound All Around.* New York: McGraw, 1958. 48 pp.

PODENDORF, ILLA. *The True Book of Sounds We Hear.* Chicago: Childrens, 1955. 47 pp.

CHAPTER

20 Light

THE NATURE OF LIGHT

I. What Light Is

A. Light is a form of energy.
1. This energy is given out, or radiated, by the sun and other light-producing bodies in the form of waves.
2. Light energy is also called **radiant energy.**

B. Light is just one part of a group of radiant energy waves, called **electromagnetic waves.**
1. This group includes **Hertzian, or radio, waves, infrared rays, light rays, ultraviolet rays, X-rays, gamma rays,** and **cosmic rays.**
2. All of these electromagnetic waves are invisible to the human eye except light rays.

C. All electromagnetic waves, including light rays, travel at a speed of 186,000 miles a second.
1. These waves move in two directions at the same time: they move up and down as they travel forward.
2. Such waves are called **transverse** waves.

D. Although electromagnetic waves travel at the same speed, the waves differ in length and in frequency.
1. The length of the wave, called the **wavelength,** is the distance between two of the waves.
2. The **frequency** of the waves is the number of waves that pass by a point in one second.
3. Electromagnetic waves with long wavelengths, such as radio waves, have a low frequency.
4. Electromagnetic waves with short wavelengths, such as X-rays, have a high frequency.

E. Although scientists know much about light and the other electromagnetic waves, they do not know the exact nature of these electromagnetic waves.
1. Scientists know that, although light travels in waves, it has certain behaviors that cannot be explained by this wave motion.
2. Scientists believe that light and other electromagnetic waves are made up of tiny bundles of energy called **quanta.**
3. These bundles of energy are given off, or radiated, and then travel in a wavelike motion.
4. The shorter the wavelength of the electromagnetic waves, the greater energy the waves will have, and the higher the frequency of the waves will be.

II. Light Travels in Straight Lines

A. Light waves travel in straight lines.
1. Light cannot travel around corners.
2. Even when light is made to change di-

rection, it continues to travel in straight lines.

3. A thin line of light is called a **ray.**
4. A beam of light is made up of many rays of light.

B. Light travels with a speed of about 186,000 miles a second, or more than 660 million miles an hour.

1. It takes about 8 minutes for light to travel the distance of 93 million miles from the sun to the earth.
2. This great speed explains why we see things happen at almost the exact moment they are happening.

C. Because the stars and planets are so far away from the earth, astronomers use the speed of light as a unit for measuring these great distances.

1. Until recently the astronomers used only the **light-year** as a unit for measuring long distances.
2. A light-year is the distance light will travel in 1 year, which is about 6 trillion miles.
3. Proxima Centauri, the star nearest the earth (not counting the sun), is more than 4 light-years (about 26 trillion miles) away.
4. Scientists now also use the **parsec** as a unit for measuring long distances.
5. One parsec is about 3¼ light-years, or about 19 trillion miles.

III. Transparent, Translucent, and Opaque Materials

A. Light can pass through some materials and is stopped by other materials.

B. Materials like air, water, and clear glass are called **transparent.**

1. When light strikes transparent materials, almost all of the light passes directly through them.
2. We can see clearly through transparent materials.

C. Materials like frosted glass and some plastics are called **translucent.**

1. When light strikes translucent materials, only some of the light passes through them.
2. The light does not pass directly through the materials, but changes directions many times, and is scattered.
3. Because light is scattered as it passes through translucent materials, we cannot see clearly through them.
4. Objects on the other side of mildly translucent materials are fuzzy and unclear.
5. With strongly translucent materials, we can see only lights and shadows.

D. Most materials are **opaque.**

1. When light strikes an opaque material, none of the light passes through the material.
2. We cannot see through opaque materials at all.
3. Most of the light is absorbed by the opaque material and is converted into heat.
4. Even in transparent and translucent materials, some of the light is absorbed and converted into heat.

IV. Shadows

A. **Shadows** are formed because light travels in straight lines.

B. Shadows are formed when an opaque material is placed in the path of rays of light.

1. The opaque material does not let the light pass through it.
2. A shadow is the dark space that is formed behind a material when the material stops rays of light.
3. The light rays that go past the edges of the material make an outline for the shadow.

C. Some parts of the shadow are darker than other parts.

1. The center part of the shadow, which gets no light at all, is the darkest part and is called the **umbra.**
2. The rest of the shadow is lighter because it gets light from some parts of the source of light, however, not from other parts, and is called the **penumbra.**

V. Sources of Light

A. Materials that give off light are called **luminous** materials.

B. Sources of light are classified either as **natural** or **artificial**, or man-made.

C. The sun is a natural source of light.
   1. It is our chief source of light.
   2. The light energy from the sun is believed to be produced by changes taking place in the nucleus of the atoms of materials in the sun.

D. Stars are also a natural source of light.

E. The moon and the planets do not produce their own light, but shine because sunlight strikes them and bounces off, or is reflected, from their surfaces.

F. Some living things, like the firefly, can produce their own light.

G. Common artificial sources of light include the **candle, kerosene lamp, gasoline lamp, electric light, fluorescent light,** and **neon light.**

H. The candle is a tube of wax, with a cotton or linen string, called the **wick,** inside the tube.
   1. When the wick is lighted, the heat melts the solid wax and a little cup of liquid wax is formed on top of the candle.
   2. The wick soaks up the liquid wax, and the heat of the burning wick then changes the liquid wax into a gas, which burns with a yellow flame.

I. The kerosene lamp works very much like the candle.
   1. The kerosene passes up the wick to the part that is burning, where the heat turns the kerosene into a gas that burns.
   2. A chimney protects the flame from drafts and helps keep the flame burning.

J. The gasoline lamp makes use of a fragile cone, called a **mantle,** that contains minerals that glow with a very white light when heated by the burning gasoline.

K. The electric light bulb contains a thin strip, or filament, of tungsten metal.
   1. When electricity flows through the filament, the filament becomes hot and glows brightly with a nearly white light.
   2. The light bulb is filled with an inactive gas, such as nitrogen and argon, instead of air.
   3. Air is not used because the oxygen in the air would make the tungsten filament burn away very quickly.

L. The fluorescent light tube has a small amount of mercury in it, and the inside of the tube is coated with certain chemicals called **phosphors.**
   1. When an electric current enters the tube, small filaments of tungsten metal at each end of the tube become hot and convert the liquid mercury into a vapor.
   2. The electric current then flows through the mercury vapor, giving off a bluish light together with many invisible ultraviolet rays.
   3. The ultraviolet rays then strike the phosphors, which produce visible light.
   4. The fluorescent lamp is cooler and gives more light for the money than the electric light bulb.

M. The neon light tube has a gas, called **neon,** in it.
   1. When a powerful electric current passes through the neon gas, the molecules of neon become excited and glow with a red color.
   2. Other gases, as well as different colored glass tubes, can be used to produce different colors.

VI. The Measurement of Light

A. Two different units of measurement are used in the measurement of light: the **candle power** and the **foot-candle.**
   1. The candle power is the unit used to measure the intensity, or strength, of the light that is given off by an object.
   2. The foot-candle is the unit used to measure the amount of light, or illumination, in a room or other place.

B. Because the candle was the principal source of light when scientists first began

to measure light, it was only natural to use the candle as a standard.

1. One candle power is the intensity of light that is produced by a standard candle.
2. A standard candle is one that has a certain size and quality.
3. Recently lighting engineers have begun to use a new unit, called the **lumen**, rather than the candle power.

C. The amount of light, or illumination, that an object receives in a room or other places depends upon two things: the candle power of the light and the distance the object is from the source of light.

1. The stronger the source of light, and the nearer the object is to the source of light, the better the illumination will be.
2. One foot-candle is the amount of light a standard candle will give at a distance of 1 foot.
3. On a clear, bright day, the sun will give as much light as about 10,000 foot-candles.

D. An instrument, called a **light meter**, is used to measure the amount of light falling upon a surface or object.

1. The light meter has in it a **photoelectric cell**, which converts light into electricity, and an **ammeter**, which measures the amount of electricity produced.
2. When light shines on the photoelectric cell, an electric current is generated.
3. The amount of electric current produced is shown by the movement of a pointer in the ammeter.
4. The brighter the light, the more current is produced, and the farther the pointer moves.
5. For convenience in reading the light meter, the face of the meter is marked off in foot-candles rather than in electrical units (amperes) to show the amount of electric current produced.

THE REFLECTION OF LIGHT

I. Light Can Be Reflected

A. For us to see an object that does not produce its own light, three things must happen.

1. There must be a source of light.
2. The light must strike the object.
3. The light must bounce off, or be reflected from, the object and then travel to the eye.

B. When light is reflected, it changes direction, but it still travels in straight lines.

C. Transparent and translucent materials allow most of the light striking them to pass through, but some light is absorbed and some light is reflected.

D. Opaque materials do not allow any light to pass through them, but absorb and reflect the light instead.

1. Such materials differ greatly in how much light they absorb and reflect.
2. Dark, rough opaque materials absorb more light than they reflect.
3. Light, smooth opaque objects reflect more light than they absorb.

II. Law of Reflection

A. When a ray of light strikes a mirror straight down, up, or forward, the ray is reflected directly back.

1. In this case we say that the ray strikes the mirror in a perpendicular line.
2. A perpendicular line has an angle of 90 degrees.

B. When a ray of light strikes a mirror at a slant, or angle, the ray is reflected at a slant, or angle, in another direction.

1. The ray that strikes the mirror is called the **incident**, or striking, ray.
2. The ray that is reflected by the mirror is called the **reflected** ray.
3. The angle between the ray of light that strikes the surface at a point and the straight, or perpendicular, line at that point is called the **angle of incidence.**
4. The angle between the reflected ray and the perpendicular line is called the **angle of reflection.**

C. The law, or principle, of reflection states that the angle of incidence is equal to the angle of reflection.

D. The law of reflection holds true for all smooth, polished surfaces.

1. When a beam of light strikes a mirror, each ray in the beam is reflected regularly.
2. Each ray has the same angle of incidence and angle of reflection so that, although the rays change direction, they all do so the same amount, and in this way continue to form a beam.

E. The law of reflection does not hold true for rough surfaces.

1. When a beam of light strikes a rough surface, each ray is reflected irregularly.
2. The rays do not have the same angle of incidence and angle of reflection so that the beam of light is scattered, or spread out, in all directions.
3. When light strikes a sheet of very smooth paper, the light is reflected regularly to the eye, and we get a glare.
4. When light strikes a sheet of coarse paper, the uneven surface reflects the light irregularly and scatters it so that we get very little glare.

III. Diffuse Reflection Is Best for Lighting in the Home

A. **Direct** lighting is light that goes directly from the source of light to the surface to be lighted.

1. Almost all of the light strikes the surface directly.
2. This direct light produces much glare, which is caused either by light striking the eye directly or by light reflected to the eye from a smooth or shiny surface.
3. A frosted glass bulb is translucent and has an uneven surface so that it scatters the light and cuts down the glare a little.

B. With **semidirect** lighting a translucent bowl or shade directs some of the light to the ceiling.

1. The uneven surface of the ceiling reflects this light irregularly and scatters it all over the room.
2. The rest of the light goes directly from the source of light to the surface to be lighted.
3. Semidirect light has much less glare than direct light.

C. With **indirect lighting** most of the light is directed upward to the ceiling, which then scatters the light all over the room.

1. The light is directed to the ceiling either by using an opaque shade or by having the source of light close to the ceiling.
2. Any light that is directed downward is scattered by using a translucent globe or shade.
3. Indirect lighting provides the most irregular reflection and the least amount of glare.

IV. The Plane Mirror

A. A **plane mirror** is usually made of a flat piece of clear glass, and the back of the glass has a thin coating of silver or some other shiny metal.

1. The light striking the mirror passes through the transparent glass, and then almost all the light is reflected back by the shiny, but opaque, silver.
2. Unbreakable mirrors can be made from highly polished steel, but these mirrors do not reflect light as well as glass ones do.

B. The objects that you see in a mirror seem to be behind the mirror, even though they are not.

1. What you really see is the reflection of objects in front of the mirror.
2. This reflection is called an **image**.
3. When you look into a mirror, you see an image of yourself.

C. The image in a mirror is reversed.
1. The image in a mirror seems to face you so that everything is reversed.
2. If you raise your right hand, your image will raise its left hand.
3. If you wink your right eye, the image will wink its left eye.

D. The image in a mirror is just as large as the object in front of it.

E. The image in a mirror seems to be just as far behind the mirror as the object is in front of it.

V. Curved Mirrors

A. When mirrors are curved, we get different kinds of images.

B. Mirrors that curve inward are called **concave mirrors**.
1. If a concave mirror curves inward just a little, the image is right-side up and larger, or magnified.
2. If a concave mirror curves inward a lot, the image is upside down and smaller.

C. If a concave mirror is curved just the right way, it will reflect rays of light that strike its surface so that all the rays come together at one spot.
1. This spot is called the **focus** of the mirror.
2. Concave mirrors are used in some astronomical telescopes to collect the light from a distant star and bring the light together so that the star may be examined.
3. Stars are too far away to be magnified, but the concave mirror in the astronomical telescope can make them very much brighter.
4. Such a telescope also helps astronomers look at stars that are too far away and faint to be seen with the naked eye.

D. Flashlights and automobile headlights also have concave mirrors made of shiny metal.
1. These mirrors act just the opposite as the mirrors in the astronomical telescopes.
2. The light bulb is placed at the focus of the mirror.
3. The rays of light coming from the bulb are reflected by the mirror to throw a beam, instead of being scattered in all directions.

E. Mirrors that curve outward are called **convex mirrors**.
1. A convex mirror does not bring rays of light together at one spot, but spreads them out in all directions.
2. Images from a convex mirror seem smaller and farther away, but the convex mirror gives you an image that covers a larger area.
3. Some rear-view auto mirrors are convex mirrors.

THE REFRACTION OF LIGHT

I. The Nature of Refraction

A. When light rays travel through a transparent material, they travel in a straight line and at the same speed.

B. But, when light rays pass at a slant, or angle, from one transparent material (such as air) into another transparent material (such as water), the light rays are bent, or refracted, so that they travel in a different direction.
1. Although the rays are now traveling in a different direction, they still travel in a straight line.

2. The light rays must pass at a slant, or angle, from one transparent material into another; otherwise they will not be bent.
3. If light rays pass from one material into another in a perpendicular line (at an angle of 90 degrees), the rays will pass straight through without being bent.

C. The light is bent because there is a change in the speed of light as it passes from one transparent material into another.
1. Light travels at different speeds through different kinds of transparent materials.
2. The difference in speed depends upon the density, or heaviness, of the material.
3. The greater the density of the material, the more slowly light will travel through it.
4. Light travels more slowly in water than air because water is denser than air.
5. Light travels more slowly in glass than water because glass is denser than water.

D. When light rays pass into a denser material at an angle, the light rays are slowed down and are bent inward.

E. When light rays pass into a less dense material at an angle, the light rays speed up and are bent outward.

F. The amount of refraction depends upon the density (heaviness) of the material.
1. The greater the density of the material, the more the light rays will be bent inward.
2. Glass is denser than water, so light rays passing from air into glass will be bent more than rays passing from air into water.

II. Lenses

A. A lens is a piece of curved glass or other transparent material.

B. The lens may be curved on one side and flat on the other side, or it may be curved on both sides.

C. Lenses are used to bend, or refract, light rays.
1. The light rays strike the lens at a slant because the surface of the lens is curved.
2. This curvature of the lens makes the rays of light bend as they pass through the lens.

D. When light rays pass through a lens, they are always bent toward the thickest part of the lens.

E. There are two kinds of lenses: convex lenses and concave lenses.

III. Convex Lenses

A. A convex lens is thick in the middle and thin at the ends.

B. Light rays passing through a convex lens are bent toward the thicker middle of the lens.
1. In this way, after passing through the lens, the rays come together and meet at a point.
2. The point at which the rays meet is called the focal point, and we say that the convex lens brings the rays into focus at this point.
3. The thicker the middle of the lens, the more the rays of light are bent and brought into focus.

C. By bending the rays of light and bringing them together, the convex lens can produce an image.

D. When a lens is placed between an object and a screen, an inverted, or upside down, image is formed on the screen.
1. When the object is far away from the lens, the image is smaller than the object.
2. The farther away the object is from the lens, the smaller the image is.
3. The closer the object is brought to the lens, the larger the image becomes.
4. When the object is close to the lens, the image becomes larger than the object.

E. When a convex lens is placed between your eyes and an object, the object appears larger, or is magnified.
1. In this case, an image that is larger than the object is formed, and it is erect, or right side up.

2. The convex lens now acts as a magnifying glass.

IV. Concave Lenses

A. A concave lens is thin in the middle and thin at the ends.
B. Light rays passing through a concave lens are bent toward the thicker ends of the lens.
   1. After passing through the lens, the rays are spread apart.
   2. The rays seem to be coming from an imaginary point behind the lens.
   3. The thicker the ends of the lens, the wider apart the rays are spread.
C. A concave lens produces only one kind of image: one that is smaller than the object, and is erect, or right side up.

V. Uses of Lenses in Instruments

A. The camera.
   1. The basic parts of a camera are a lightproof box, an opening in front of the camera, a shutter over the opening, a convex lens behind the opening, a film at the back of the camera, and a device to hold and turn the film.
   2. The shutter lets light enter the camera and strike the lens, which bends the light rays so that they come together, or are brought into focus, at the film.
   3. The film is coated with chemicals that are affected by light.
   4. When light rays are brought together at the film, a chemical change takes place.
   5. The film is then treated with chemicals and becomes a "negative," where the dark parts of the object appear light and the light part appear dark.
   6. The "negative" is also treated with chemicals to become a "positive," where the dark parts of the "negative" now become light and the light parts become dark, just as they were in the original object.
   7. In inexpensive cameras the lens is fixed so that it can only bring into sharp focus light rays coming from objects that are more than 6 feet away from the camera.
   8. In more expensive cameras the lens can be moved back and forth so that it can bring into sharp focus light rays coming from both near and far objects.
B. The microscope.
   1. A microscope has two convex lenses, which are placed at each end of a lightproof tube.
   2. The upper lens is called the **eyepiece**, and the lower lens is called the **objective**.
   3. Rays of light from an object pass through the lens of the objective and are bent, producing an enlarged image of the object inside the tube.
   4. The lens of the eyepiece acts like a magnifying glass and magnifies this image even more, making it many times larger than the object.
   5. To focus the microscope, one part of the tube is made to slide up or down inside another part.
C. The telescope.
   1. The **reflecting telescope** has a large concave mirror at one end, and at the other end there is a small convex lens that magnifies the image produced by the mirror.
   2. The **refracting telescope** works very much like the microscope, with an objective and an eyepiece.
   3. A very large convex lens in the objective collects all the light it can from a distant object and bends the light rays to produce an image, which is magnified by the smaller convex lens in the eyepiece.
   4. One part of the tube slides in and out of another part of the tube to bring objects located at different distances into focus.
   5. **Binoculars** and **opera glasses** are really two refracting telescopes connected side by side, one for each eye.
   6. Prisms in the binoculars and opera

glasses reflect the light rays so that the image is seen right side up.

D. Projectors

1. All projectors use one or more convex lenses to change a small film photograph into a large image on a screen.
2. A strong beam of light shines through the transparent film, and a convex lens bends the rays of light coming from the film to produce the large image on the screen.
3. Projectors are widely used in schools.

COLOR

I. The Spectrum

A. When a narrow beam of sunlight passes at a slant into a triangular transparent material, called a **prism**, the sunlight is broken up into a band of colored lights, which can be seen on a white wall or screen.

1. This band of colored lights is called the **spectrum.**
2. There are seven colored lights in the spectrum: violet, indigo, blue, green, yellow, orange, and red.
3. Sometimes blue and indigo are treated as one color.

B. When a second prism (or a convex lens) is placed at just the right position in front of the rays of colored light coming from a prism, the rays of colored light combine to form white light again.

C. White light, then, is really a mixture of the seven colored lights of the spectrum.

D. These colored lights are called **pure** colored lights because each light cannot be broken up any further by another prism.

E. A prism breaks up white light into a spectrum because the colored lights that make up the spectrum all have different wavelengths.

1. Violet light has the shortest wavelength, red light the longest wavelength, and the wavelengths of the other colored lights are in between those of violet and red light.
2. When white light enters a prism at a slant, the prism bends, or refracts, the different colored lights in different amounts.
3. The lights with the shorter waves are bent more than lights with the longer waves.
4. Violet light has the shortest waves and is bent the most, and red light has the longest wave and is bent the least.
5. The other colors are bent in different amounts so that all seven colored lights that make up white light are separated as they pass through the prism, and strike a screen at different places to form a band of colors.

II. Rainbows

A. A **rainbow** is a spectrum that is produced when the sun shines during or immediately after a rain shower.

B. The raindrops act as tiny prisms and break the sunlight up into a spectrum in the form of a large, beautiful arch.

C. An artificial rainbow can be made by spraying with a garden hose with your back to the sun, either early in the morning or late in the afternoon, when the sun is low.

III. Primary and Complementary Colors

A. A colored light is only a part of white light.

B. To get a single colored light from white light, all the other colored lights except

the one you want must be taken away, or absorbed.

1. When white light is passed through a transparent colored material, such as red cellophane, all the colors in white light are absorbed except the red light that is allowed to pass through the cellophane.
2. The colored light is always dimmer than white light because the rest of the colored lights have been absorbed.
3. The lights that have been absorbed are converted into heat.

C. Red, green, and blue colored lights are called **primary** colors.

1. Every shade of colored light can be made by mixing different combinations of these colored lights.
2. All three primary colors together produce white light.

D. Any two colors that, when mixed together, produce white light are called **complementary** colors.

E. The following pairs of colors are complementary colors.

1. Red and bluish-green.
2. Orange and greenish-blue.
3. Yellow and blue.
4. Green and purplish-red.
5. Violet and greenish-yellow.

IV. Colored Materials

A. A material is colored because, when white light strikes the material, all the colored lights have been absorbed except one, which is reflected to the eye.

1. A red dress looks red because the material absorbs all the colors of white light except red, which is reflected to the eye.
2. Grass appears green because it absorbs all the colors except green, which it reflects to the eye.
3. The colored lights that have been absorbed are converted into heat.

B. A white material appears white because all the colored lights are reflected to the eye.

C. A black material appears black because all the colored lights are absorbed so that not one light is reflected to the eye.

D. The color of a material also depends upon the kind of light shining on it.

1. When red light shines on a white material, the material appears red because the red light is the only color striking the white material, so red is the only color that can be reflected to the eye.
2. When blue light shines on a red material, the material appears black because the material can only reflect red light, and there is no red in the blue light shining on the material.

E. Colors may seem different in artificial light because this light has less blue and more red in it than sunlight.

1. In artificial light blue may seem to be almost black because there is so little blue to be reflected.
2. At the same time red seems to be much brighter because the artificial light has so much red that can be reflected.

F. Red, yellow, and blue are called the primary colors of paints.

1. Every other color can be produced by mixing different combinations of these colored paints.
2. Red and yellow paints make orange.
3. Red and blue paints make purple.
4. Yellow and blue paints make green.
5. Black and orange paints make brown.
6. Black and white paints make gray.

G. Mixing colored paints produces effects entirely different from those produced by mixing colored lights.

1. Most colored paints are not completely pure, so they also reflect small amounts of other colors.
2. Yellow paint usually reflects a little green light as well as yellow light.
3. Blue paint also reflects some green light as well as blue light.
4. When yellow paint and blue paint are mixed together, the mixture becomes green.
5. The yellow paint absorbs the blue light

and the blue paint absorbs the yellow light.

6. Neither paint absorbs the green light so that green is the only color reflected to the eye.

H. When red, yellow, and blue paints are mixed together, the mixture becomes black.
1. All the colors have been absorbed and none is reflected to the eye.
2. Black is not really a color, but rather the absence of all color.

V. The Color of the Sky and the Sun

A. During the day the sky looks blue and the sun yellowish-white.

B. This effect is caused by the presence of dust in the air.
1. The sky looks blue because some of the blue color of sunlight is scattered by the dust and reflected to the eye.
2. The yellow and red colors of sunlight are not scattered, but rather pass straight through, so that the loss of some of the blue color of sunlight makes the sun look yellowish-white.

D. At sunrise and sunset the sunlight must travel at a greater slant, or angle, and it passes through more air and dust than before.
1. The blue color of sunlight is now scattered much more by the dust in the air, so that there is even less blue passing straight through.
2. The loss of more of the blue color of sunlight now makes the sun look reddish or orange.
3. The moisture in the clouds also absorbs green and blue from the sunlight, producing a still greater effect of reds, oranges, and yellows at sunrise and sunset.

ELECTROMAGNETIC RADIATIONS

I. The Electromagnetic Spectrum

A. Light rays are just one small part of a group of radiant energy waves, called **electromagnetic waves.**
1. This group includes **radio waves, infrared rays, light rays, ultraviolet rays, X-rays, gamma rays,** and **cosmic rays.**
2. All of these electromagnetic waves are invisible to the human eye, except light rays.
3. We recognize the other waves by the effects they produce.

B. All electromagnetic waves are transverse waves, which move in two directions at the very same time: up and down, and forward.

C. All these waves travel at a speed of 186,000 miles a second.

D. Electromagnetic waves differ in length and in frequency, even though they all travel at the same speed.
1. The length of a wave, called the **wave-length,** is the distance between two of the waves.
2. The **frequency** of a wave is the number of waves that pass by a point in 1 second.

E. Some electromagnetic waves have wavelengths as short as a trillionth of an inch or as long as 200 miles.

F. Some electromagnetic waves have a frequency as low as 10 kilocycles or as high as 300 million megacycles.
1. A **cycle** is one complete up and down movement of a wave.
2. The frequency of a wave, then, is also the number of cycles that take place in 1 second.
3. In a 60-cycle wave, the wave moves up and down 60 times in 1 second so that 60 complete waves pass by a point in 1 second.
4. Because electromagnetic waves have very high frequencies, the frequency is usually given in **kilocycles** (thousands

of cycles) or **megacycles** (millions of cycles).

G. Electromagnetic waves with long wavelengths have low frequencies, whereas those waves with short wavelengths have high frequencies.

H. Together all these different waves of radiant energy make up the electromagnetic spectrum.
   1. At one end of this spectrum are those waves with long wavelengths and low frequencies.
   2. At the other end of the spectrum are those waves with short wavelengths and high frequencies.

II. Waves with Long Wavelengths and Low Frequencies

A. Waves of this kind include **infrared rays** and **Hertzian, or radio, waves.**

B. Infrared rays are a band of invisible waves that are able to produce very much heat energy.
   1. Infra means "below," and infrared rays are the first band of rays below visible red light rays.
   2. Almost half of the sun's energy comes to us as infrared rays.
   3. Infrared rays are used in taking pictures in the dark, in obtaining special photographic effects, in detecting fingerprints or changes in documents and paintings, and in medicine.

C. Hertzian or radio waves are a very wide band of invisible rays that are used in all kinds of communication.
   1. This band of rays is found below the infrared rays.
   2. The band is so wide that it is subdivided into smaller bands or channels.
   3. Each channel is set aside and used for a different purpose.
   4. The waves in each band or channel are often identified by their frequencies (kilocycles and megacycles) instead of their wavelengths.
   5. Separate channels are used for AM radio, FM radio, television, police calls, military communications, radar, amateur broadcasting, aviation, and distress signals.

III. Waves with Short Wavelengths and High Frequencies

A. Waves of this kind include **ultraviolet rays, X-rays, gamma rays, and cosmic rays.**

B. Ultraviolet rays are a band of invisible waves found just beyond visible violet light rays.
   1. Ultra means "beyond," and ultraviolet rays are the first band of rays beyond visible violet light rays.
   2. Ultraviolet rays come from the sun and can produce severe, painful burns.
   3. Ultraviolet rays can also be produced when an electric current flows through mercury vapor.
   4. When the invisible ultraviolet rays strike certain chemicals, called **phosphors,** the chemicals glow and give off visible light.
   5. This effect is used in fluorescent lamps and for identifying marks made on clothing by the laundry.
   6. Ultraviolet light is also used for scientific research, in special lamps to kill germs, in advertising, and in safety-warning devices.

C. X-rays are a band of waves found beyond the ultraviolet rays.
   1. They have a shorter wavelength and higher frequency than ultraviolet rays.
   2. These rays can pass through nonmetals and through thin sheets of most metals.
   3. The rays are stopped by thicker sheets of metals and by certain metallic salts, such as barium sulfate.
   4. X-rays are used to take pictures of the bones and organs in the body, detect cracks in metals, and inspect fruits to see if they have been damaged by frost.

D. Gamma rays are very tiny electromagnetic waves.
   1. They are found beyond the band of X-rays.

2. Radioactive materials give off gamma rays.

E. Cosmic rays are found beyond the band of gamma rays.

1. Cosmic rays are not true electromagnetic waves, but act as if they were tiny particles traveling at the speed of light.
2. These tiny particles that make up cosmic rays come from outer space and strike the earth and the atmosphere.
3. Scientists know very little about cosmic rays.

LEARNING ACTIVITIES FOR "LIGHT"

THE NATURE OF LIGHT

1. *Show transverse waves* · Obtain about 12 to 15 feet of clothesline rope. Attach one end of the rope to a door handle. Shake the other end up and down to form transverse waves (Figure 20–1). Note that the waves move up and down as they travel forward. Draw a series of these waves on the chalkboard. Mark off one wavelength. Point out that the number of these waves passing by a fixed point in 1 second would be the frequency of these waves. Show the relationship between wavelength and frequency.

FIGURE 20–1.
MAKING A ROPE PRODUCE TRANSVERSE WAVES.

2. *Light travels in straight lines* · Obtain four index cards the same size and find their center by drawing diagonals on each card. Make a good-sized hole at this center, and then attach each card with thumb tacks to a small block of wood (Figure 20–2). Place the index cards one in front of the other, several inches apart, making sure that the holes are in a straight line with each other. Rest a flashlight on some books placed 2 to 3 feet from the first card, making sure that the height is just right for the flashlight to shine directly through the holes.

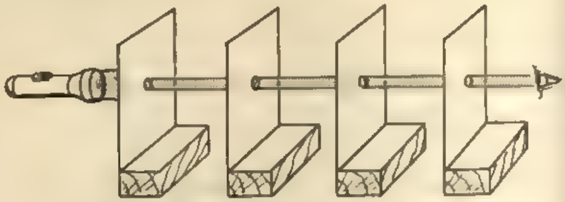


FIGURE 20–2.
LIGHT TRAVELS IN A STRAIGHT LINE THROUGH THE HOLES IN THE INDEX CARDS.

Turn on the flashlight, and then darken the room. Have a child look through all four holes and see the light of the flashlight. Point out that the light can be seen only because it is passing through each hole in a straight line. If you clap two chalkboard erasers along the path of the light, the children will be able to see a beam of light in a straight line. Now move one of the cards so it is out of line. The child will not be able to see the light because the light traveling in a straight line is stopped by the card.

3. *Make a light-ray box* · Obtain a large rectangular cardboard carton and remove the flaps to create an open side. Put the carton down so that the open side is at the back. Remove most of the top and front side of the carton and replace with clear cellophane or

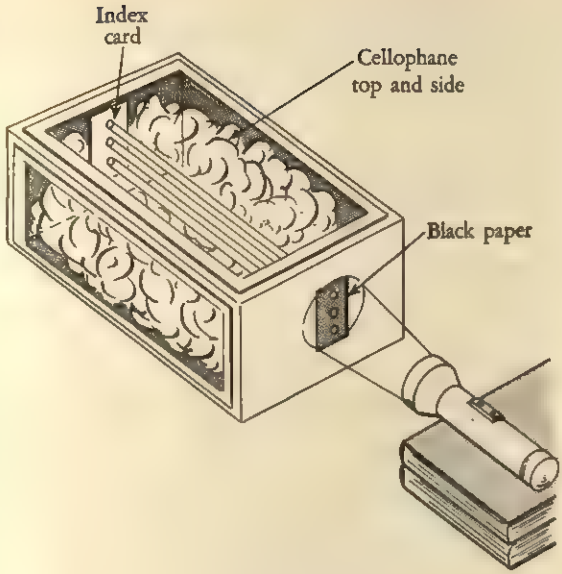


FIGURE 20–3.
A LIGHT-RAY BOX.

plastic, taping the cellophane firmly to the carton (Figure 20–3). Paint the inside cardboard of the carton with flat, black paint.

Obtain two pieces of black cloth, each slightly larger than half of the length of the carton, and tack them to the open back in such a way that they overlap at the middle. You can now put your hand inside the carton without permitting any light to enter. Halfway down one end of the carton, nearer the front, cut out a window about 3 inches long and 2 inches wide. Obtain a piece of black construction paper slightly larger than the window, punch out three holes, one underneath the other, and then tape the paper over the window. Tape a 3 × 5 white index card on the inside of the other end of the carton, directly opposite to the black paper. The white card will act as a screen.

Fill the carton with smoke by burning a cigarette, rope, damp paper, incense, or punk in an ash tray. Obtain a three-cell focusing flashlight and rest it on some books placed 2 to 3 feet away from the carton, making sure the height is such that light from the flashlight will shine directly through the holes. Turn on the flashlight, and then darken the room. Three parallel rays of light will be clearly visible inside the carton. Note that the rays are parallel, showing that light travels in straight lines.

4. *The speed of light* · Have the children read about and report on how the speed of light was determined. Let them calculate the time it takes for the sun's rays to reach the earth 93 million miles away. Some children may be interested in calculating the distance traveled in one light-year. This distance can be found by multiplying 186,000 by 60 seconds, then by 60 minutes, then by 24 hours, and then by 365¼ days. Multiplying this answer by 3⅓ will give the distance traveled in a parsec.

5. *Transparent, translucent, and opaque materials* · Darken the room and aim a beam of light from a focusing flashlight at a clear pane of glass. A distinct spot will be seen on the wall as the light passes directly through the transparent material. Now aim the beam at a pane of frosted glass or a piece of wax paper. Light will pass through, but it will be dispersed by the translucent material and there will not be a spot on the wall. Aim the beam of light at a square of cardboard. None of the light will pass through the opaque material.

Place a lighted candle behind the clear pane of glass. You will see the candle clearly through the transparent material. Repeat, using frosted glass or wax paper, and the candle will not be seen clearly through the translucent material. You will not be able to see the candle at all through opaque cardboard.

6. *Create shadows* · Place a screen at one end of the room. Remove the shade from a table lamp or gooseneck lamp and place it on a table about 12 to 15 feet away from the screen. Turn on the lamp and darken the room. Suspend a styrofoam ball between the lamp and the screen, and note the shadow cast on the screen. If the ball is quite close to the screen, only an umbra will be seen. If the ball is

nearer the lamp, both an umbra and penumbra will be seen.

7. *Sources of light* · Have the children read about and report on such sources of light as the sun, torch, candle, kerosene lamp, gas lamp, gasoline lamp, electric light, fluorescent light, and neon light. Let them describe how each source is produced. Make a display or exhibit of as many of these sources as are available.

8. *The measurement of light* · Use a lightmeter to measure the illumination at different parts of the classroom and the school building. Have a child bring in a camera with a built-in lightmeter and explain its operation.

THE REFLECTION OF LIGHT

1. *Light can be reflected* · Set up a light-ray box as described in Learning Activity 3 of "The Nature of Light" (p. 710). Hold a plane mirror at an angle of 45 degrees in the box and note how the light is reflected (Figure 20–4). Hold the mirror at different angles and observe the effect on the reflection of light. When you hold the mirror vertically (at an angle of 90 degrees), the rays will be reflected directly back to their source.

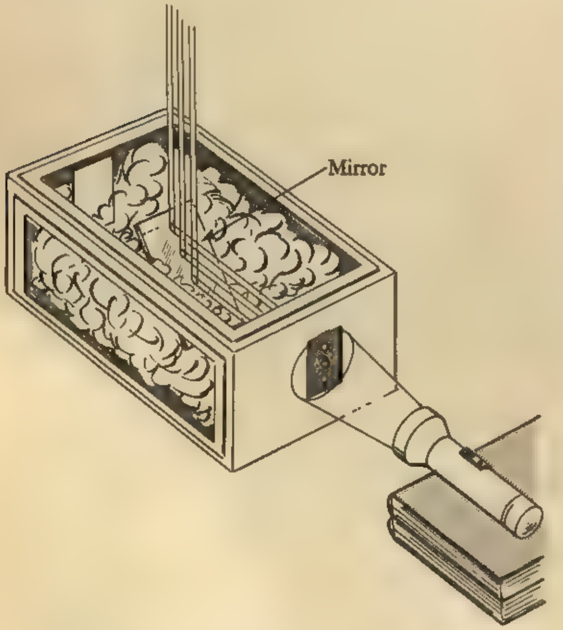


FIGURE 20–4.
LIGHT IS REFLECTED BY A PLANE MIRROR.

2. *The law of reflection* · Place a large plane mirror at the center of a table. Darken the room, and then turn on a focusing flashlight and aim it at an angle at the mirror. The light will be reflected and appear on the wall. Have a child clap two chalkboard erasers over the mirror and on each side of the mirror (Figure 20–5). Two rays of light, an incident and a reflected ray, will appear. Change the angle at which the ray strikes the mirror and note how the angle of the reflected ray changes accordingly. Point out that the angle of incidence and angle of reflection are always equal.

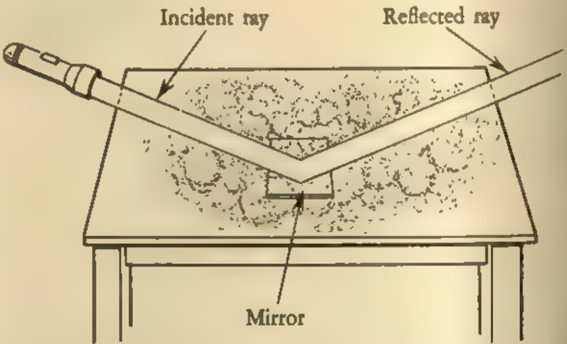


FIGURE 20–5.
ILLUSTRATING THE LAW OF REFLECTION.

3. *Reflection from smooth and rough surfaces* · Repeat either Learning Activity 1 or 2 above, first using a plane mirror alone, and then taping a piece of wax paper over the mirror. Note how the rays of light are reflected irregularly and scattered by the rough surface of the wax paper.

4. *Reflection from light and dark surfaces* · Repeat Learning Activity 2 of "Winds," Chapter 11 (p. 382), showing that light surfaces reflect more of the sun's rays than dark surfaces.

5. *Lighting in the home* • Have the children read about and report on direct, semidirect, and indirect lighting. Discuss which kind of lighting is best for use in the home.

6. *Reflection in plane mirrors* • Stand in front of a large mirror and raise your right hand. Your image will raise its left hand, showing that the image is reversed. Note that your image is the same size as you are. Step back two paces. Your image will be just as far behind the mirror as you are in front of it.

7. *Light can be reflected again and again by mirrors* • Have a child sit or crouch next to the wall where the window is located. Give the child two mirrors and have him hold them in the position as shown in Figure 20–6. By tilting

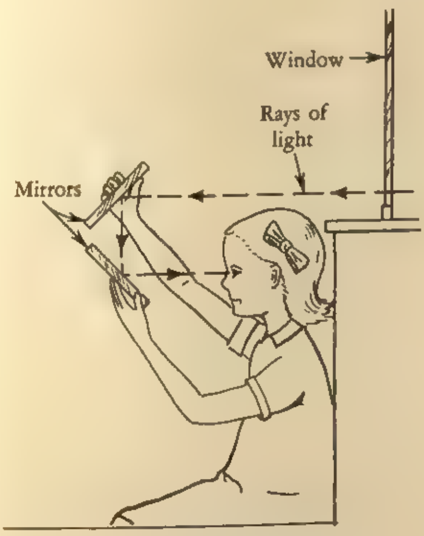


FIGURE 20–6.
A PERISCOPE WORKS BY REFLECTING LIGHT MORE THAN ONCE.

both mirrors at the proper angles, the child will be able to see objects outside the window. Draw a diagram on the chalkboard to show how the light from the window strikes the top mirror, is reflected to the lower mirror, and then reflected again to the child's eye. Point out that this is how a periscope works.

8. *Plane glass can act as a mirror* • Obtain a large piece of window glass and tape a piece of white paper over one side. Turn on a table lamp and darken the room. Stand with your back to the lamp and hold up the glass and look at it, keeping the white paper behind the glass. You will see a very faint reflection because most of the light passing through the glass and striking the white paper is reflected irregularly and scattered. Now replace the white paper with a piece of black paper. You will see a very clear reflection because the black paper absorbed the light striking it, allowing a small amount of light to be reflected regularly from the surface of the glass.

9. *Reflection in a concave mirror* • Obtain a magnifying glass or beauty mirror and have a child look at it. Point out that the mirror is a concave mirror that curves inward just a little. This is the reason why the image is right side up and magnified.

Obtain a large, highly polished, silver tablespoon. Look at the concave (hollow) side of the bowl. This concave mirror curves inward a lot, and thus your image is upside down and smaller.

10. *Reflection in a convex mirror* • Obtain a large, highly polished, silver tablespoon. Hold the spoon vertically and look at the convex (bulging) side of the bowl. You will see a long, thin image of yourself that is smaller and right side up. Now hold the spoon horizontally and look again. The image becomes short and fat, but still is small and right side up.

THE REFRACTION OF LIGHT

1. *Light can be refracted* • Fill a rectangular aquarium about three-quarters full of water and keep adding drops of milk until the water has a cloudy appearance. Darken the room, and then turn on a focusing flashlight and aim it at an angle at the aquarium (Figure 20–7). At the same time have a child clap two chalkboard erasers over the aquarium to outline the

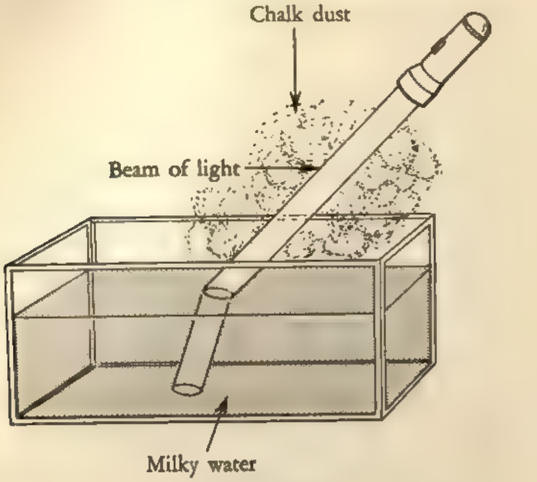


FIGURE 20–7.
THE LIGHT IS REFRACTED WHEN IT ENTERS THE WATER.

path of the beam of light coming from the flashlight. The beam of light will be bent inward as it passes from the air into the water. Now hold the flashlight so that the beam of light enters the water vertically (at an angle of 90 degrees). The beam will pass from the air into the water without being refracted.

2. *A convex lens causes light rays to converge* · Set up a light-ray box as described in Learning Activity 3 of "The Nature of Light" (p. 710). Hold a magnifying glass (convex lens) in the box and note how the rays of light converge and meet at a point (Figure 20–8).

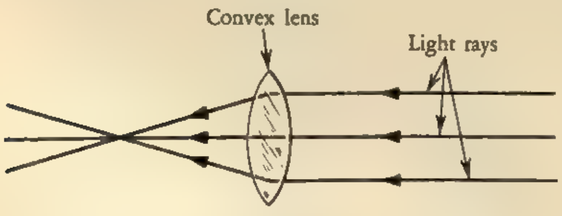


FIGURE 20–8.
A CONVEX LENS CONVERGES RAYS OF LIGHT.

Move the magnifying glass back and forth until the rays of light meet at a point on the white index card. Then move the magnifying glass so that the rays of light converge, and then spread out again. Note how the rays travel in straight lines, even after they are bent.

Repeat Learning Activity 7 of "The Nature of Heat," Chapter 18 (p. 673), showing how a convex lens converges the sun's rays so that they meet at a point on a match head, causing it to burst into flame.

3. *Images formed by a convex lens* · Use a spring-type clothes pin to hold a large, rectangular, white cardboard vertically on a table. Place a lighted candle about 2 to 3 feet away from the cardboard. Hold a magnifying glass near the cardboard and move the magnifying glass slowly toward the flame until a clear, inverted, smaller image of the candle appears on the cardboard (Figure 20–9).

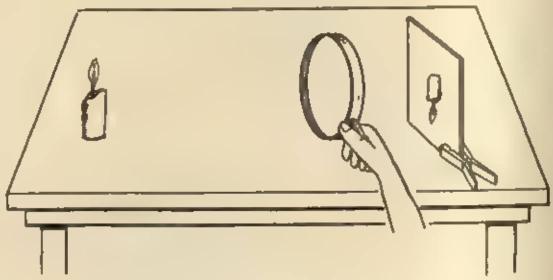


FIGURE 20–9.
A CONVEX LENS HELD FAR FROM AN OBJECT WILL PRODUCE AN INVERTED, SMALLER IMAGE.

Now hold the magnifying glass close to the candle and move the magnifying glass slowly toward the cardboard until a clear, inverted, larger image of the candle appears on the cardboard. You may have to push the cardboard farther back to obtain this image. Point out that when the object is close to the lens, you get a large image. When the object is far from the lens, you get a small image. Both images are upside down.

Now use the glass as a magnifying instrument by placing the glass between your eyes and an object. When used this way, the image produced is larger and right side up.

4. *A concave lens causes light rays to diverge* · Set up a light-ray box as described in Learning Activity 3 of "The Nature of Light" (p. 710). Obtain a concave lens from a scientific supply house or your local optometrist. Hold the concave lens in the box and note how the rays of light spread out, or diverge (Figure 20–10).

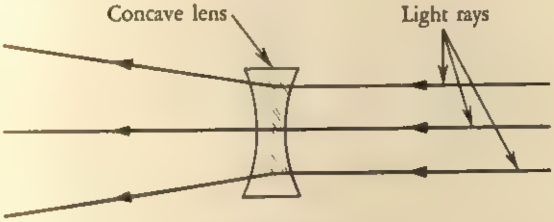


FIGURE 20–10.
A CONCAVE LENS DIVERGES RAYS OF LIGHT.

5. *Image formed by a concave lens* · Hold a concave lens between your eyes and a picture or words in a book. The picture and words will become smaller. Point out that a concave lens produces just one kind of image: an erect and smaller one.

6. *Water can act as a lens* · Insert your thumb in a glass tumbler of water and look at it from the side of the glass. The water has assumed the curved shape of the tumbler and has become a convex (magnifying) lens. This change will explain why fish and food (such as olives) are magnified when placed in curved containers.

7. *Light and vision* · Repeat Learning Activities 4 to 12 of "The Sense Organs," Chapter 15 (pp. 595–597), showing wherever possible the relationship between light and vision.

8. *Compare the eye and the camera* · Display a camera and a model or diagram of the eye. List the key parts of each, describe their function, and then determine which parts of the eye correspond with those of the camera. Now show how the eye and the camera differ.

9. *The use of lenses in instruments* · Have the children read about and report on the part lenses play in the function of such instruments as the camera, microscope, and telescope.

COLOR

1. *Make a spectrum* · On a sunny day, when the sun's rays are coming through the window into the classroom, hold a prism in the path of the sunlight. Roll the prism around until you are able to throw a rainbow on the wall (Figure 20–11). Have a child tape a white cardboard to the wall so that the spectrum will show up more clearly. Ask the children to locate and identify the different colors of the spectrum.

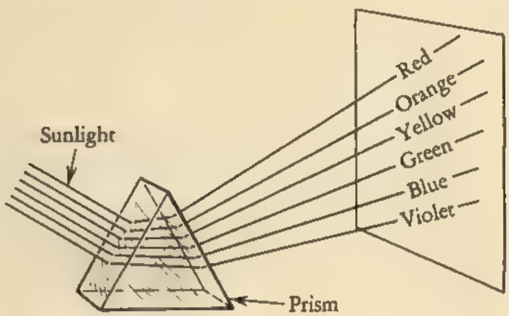


FIGURE 20–11.
A PRISM PRODUCES A BAND OF COLORED LIGHTS.

2. *The colored lights of a spectrum can be recombined* · Repeat Learning Activity 1 above, but now place a magnifying glass (convex lens) between the prism and the cardboard (Figure 20–12). Move the magnifying glass back and forth until you make the spectrum disappear and there is only a spot of white light on the cardboard. Point out that the convex lens of the magnifying glass caused the colored lights of the spectrum to converge and combine, forming white light again.

3. *Make a rainbow* · Take the children out-

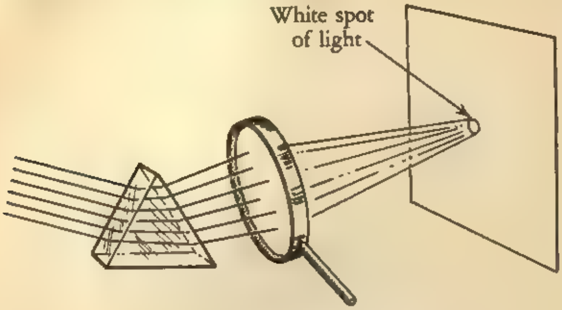


FIGURE 20–12.
A CONVEX LENS RECOMBINES THE SPECTRUM TO FORM WHITE LIGHT AGAIN.

side on the school lawn in the early morning or late afternoon. Stand with your back to the sun, facing a dark background if possible. Adjust the water from a garden hose so that a fine spray is produced. Now spray the water upward. A rainbow is produced as the water droplets, acting like tiny prisms, break up the sun's rays to form a spectrum.

Make and trap a rainbow by allowing one drop of Duco cement to fall into a clean glass pie plate full of water. The cement will spread out on top of the water to form a thin film with rainbow colors in it. Slide a piece of black construction paper under the film and carefully lift it out of the water. You will have trapped a rainbow permanently.

4. *Produce colored lights* · Turn on a focusing flashlight and darken the room. Have a child clap two chalkboard erasers together in front of the flashlight. Note the beam of white light coming from the flashlight. Now wrap a piece of red cellophane smoothly around the glass of the flashlight. The beam of light is colored red because the cellophane absorbs all the colors of the spectrum except the red light, which is allowed to pass through. Produce other beams of colored light by using differently colored pieces of cellophane.

5. *Combining primary and complementary colors* · Draw a circle 3 or 4 inches in diameter and then on a piece of white cardboard, cut out the circle. Draw three equal sections on the cardboard and color them red, green, and blue with wax crayons. Make two small holes near the center of the circle and pass a loop of string through them (Figure 20–13). Now make the

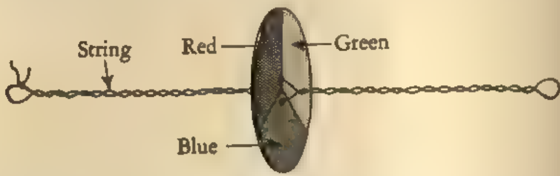


FIGURE 20–13.
COMBINING PRIMARY COLORED LIGHTS PRODUCES WHITE LIGHT.

circle spin rapidly by twisting the string, stretching it, and then allowing it to rewind. Continue stretching and rewinding to keep the card spinning constantly. When the card is spinning, these primary colors will blend together to form a grayish white. (If one color shows up predominantly, scrape a little of it off and replace it with more of the other two colors. Usually more blue is needed.) To prevent the string from cutting through the holes and make them too big for effective spinning, glue the cardboard circle to a large button, lining up the holes of the cardboard with those of the button.

Repeat the activity, using another cardboard circle containing just two complementary colors, such as yellow and blue. The complementary colors will blend together when the circle is spinning, forming grayish white again.

6. *Colored materials* · Call the children's attention to the color of their clothes and of other objects such as pens, pencils, chalk, crayon, and book covers. Point out that each material has a certain color because, when white light strikes the material, all the colored lights have been absorbed except one, which is reflected to the eye.

7. *The effect of colored lights on the color of materials* · Place a large china saucer on a

plate. Pour several tablespoons of alcohol into the saucer, add 2 or 3 tablespoons of table salt or borax, and stir thoroughly. Darken the room and set the alcohol on fire with a lighted match. The burning alcohol will heat the salt or borax and produce a pure yellow flame.

Hold a piece of white cloth near the flame. The cloth will appear yellow because only yellow light is striking the cloth and being reflected to the eye. Hold a piece of yellow cloth near the flame. The cloth will still appear yellow. Now hold a piece of red cloth near the flame. The cloth will appear black because it can only reflect red light, and there is no red light shining on the cloth. Hold other colored cloths near the flame, and note that they all appear black. Let the flame shine directly upon you. Your face will appear to be a mixture of yellow and black to the children.

8. *Combining colored pigments* · Draw streaks of yellow and blue tempera paints separately on a piece of white cardboard. Now mix both colors and explain why the green color results. Repeat, using such combinations as red and yellow, red and blue, and black and orange. Mix the six spectrum colors together (or just red, yellow, and blue paints) and note that the mixture becomes black because it absorbs all the colors of the white light striking it and reflects none. Compare this effect with the mixing of colored lights in Learning Activities 2 and 5 above.

ELECTROMAGNETIC RADIATIONS

1. *The electromagnetic spectrum* · Draw a diagram on the chalkboard showing the electromagnetic spectrum (Figure 20–14). Show the relationship between wavelength and frequency. Note that the visible light waves in the center are only a small portion of the entire electromagnetic spectrum.

2. *Electromagnetic waves are transverse waves* · Repeat Learning Activity 1 of "The Nature of Light" (p. 710). Develop the concept of the cycle, kilocycle, and megacycle.

3. *Infrared waves* · Have the children read about and report on the use of infrared waves in photography, medicine, and chemistry.

4. *Hertzian or radio waves* · Have the children read and report on the use of Hertzian or radio waves in communication. Ask the children to designate the subdivision of this broad band of rays into smaller bands or channels, and state the special purpose for each channel.

5. *Ultraviolet rays* · Have the children read about and report on where ultraviolet rays are found, the burns they can produce, their effect on phosphors to produce fluorescence, and their uses in science, medicine, and industry.

6. *X-rays* · Borrow some X-ray photographs

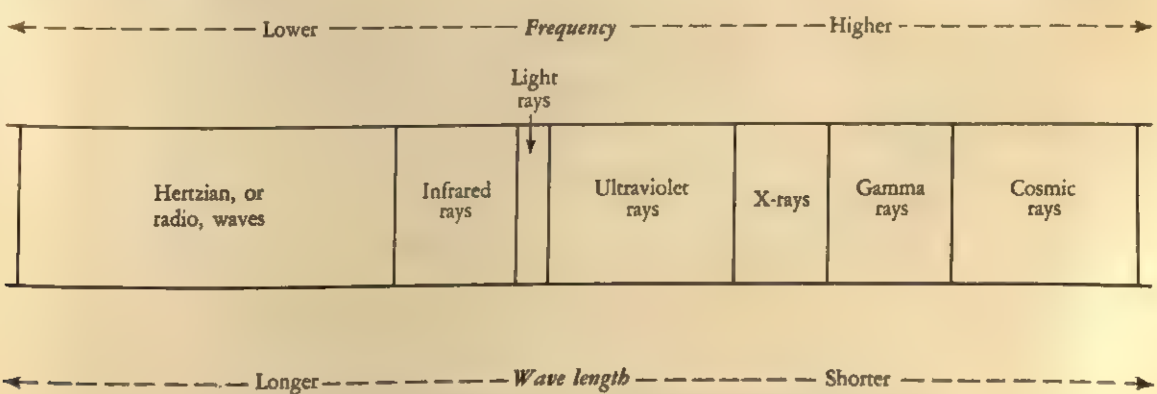


FIGURE 20–14. DIAGRAM OF THE ELECTROMAGNETIC SPECTRUM.

of bones and other parts of the body from your local doctor and let the children examine them. Have the children read about and report on the uses of X-rays in medicine and in industry.

7. *Gamma rays* · Have the children read about and report on the emission of gamma rays by radioactive materials. Let them describe the harmful effects these rays can produce.

BIBLIOGRAPHY FOR "LIGHT"

ADLER, IRVING. *The Secret of Light.* New York: Int. Pubs., 1952. 96 pp.

FARQUHAR, MARGARET C. *Lights.* New York: Holt, Rinehart & Winston, 1960. 48 pp.

PARKER, BERTHA M. *Light.* New York: Harper, 1956. 36 pp.

PASCHEL, HERBERT P. *The First Book of Color.* New York: Watts, 1959. 45 pp.

PERRY, JOHN. *Our Wonderful Eyes.* New York: McGraw, 1955. 158 pp.

PINE, TILLIE S., and JOSEPH LEVINE. *Light All Around.* New York: McGraw, 1961. 48 pp.

RUCHLIS, HY. *The Wonder of Light.* New York: Harper, 1960. 154 pp.

SCHARFF, ROBERT. *Rays and Radiation.* New York: Putnam, 1960. 72 pp.

SUTTON-VANE, S. *The Story of Eyes.* New York: Viking, 1958. 221 pp.

TANNENBAUM, BEULAH, *and* MYRA STILLMAN. *Understanding Light.* New York: McGraw, 1960. 144 pp.

CHAPTER

Magnetism *and* Electricity 21

MAGNETISM

I. Magnets

A. Magnets are materials that will pick up or attract materials made of iron, steel, cobalt, and nickel.

B. Such materials are called **magnetic materials.**

C. There are two kinds of magnets: natural magnets and man-made magnets.

D. Natural magnets are found in the ground, and are called **lodestones.**

1. They contain an iron ore called **magnetite.**
2. They look like rocks and are irregular in shape.

E. Man-made magnets can be made only from iron, steel, cobalt, and nickel (magnetic materials).

1. Sometimes aluminum is added to these materials, making light but very strong magnets called **Alnico** magnets.
2. Man-made magnets are given the following names according to their shapes: **bar** magnets, **horseshoe** magnets, and **U-shaped** magnets.

II. The Law of Magnetic Attraction

A. The force (push or pull) of a magnet is strongest at its ends, which are called **poles.**

B. A man-made magnet always has two poles: a **north-seeking** pole and a **south-seeking** pole.

1. When a magnet is allowed to swing freely in space, its north-seeking pole points toward the north and its south-seeking pole points toward the south.
2. This is the reason why the poles are called north-seeking and south-seeking.

C. A natural magnet (lodestone) has many poles, but there are always just as many north-seeking poles as there are south-seeking poles.

D. When the poles of two magnets are brought near each other, they obey the **law of magnetic attraction,** which states that two unlike poles attract each other and two like poles repel each other.

III. The Magnetic Field

A. The space around a magnet also can act like a magnet.

B. This space, around which the force of a magnet acts or is felt, is called the **magnetic field.**

C. If iron filings are sprinkled around a magnet, the filings arrange themselves into a pattern of lines.

D. These lines are called **lines of force,** and they show where the magnetic field is located and how it is arranged.

E. There are more lines of force, bunched

closely together, at the ends (poles) of the magnet, where the magnetic force is strongest, than at the middle of the magnet.

IV. The Force of a Magnet Can Pass Through Many Materials

A. A magnet can attract magnetic materials (iron, steel, cobalt, nickel) without even touching them.

B. This attraction occurs because the force of a magnet can pass through any material that is not magnetic, such as air, paper, wood, glass, aluminum, and brass.

C. The nearer the magnetic material is to the poles of a magnet, the stronger the force of attraction will be.

D. The force of a magnet does not pass through magnetic materials because these materials hold or keep nearly all of the magnetic force so that practically none of the force can pass through.

V. The Nature of Magnetism

A. At first scientists believed that magnetism in a magnetic material was due to the nature and arrangement of the molecules inside the magnetic material.

1. They believed that every molecule in a magnetic material behaved as if it were a tiny magnet, with a north-seeking and a south-seeking pole.
2. When the magnetic material was not magnetized, the molecules were arranged in a haphazard way so that the poles neutralized (or acted against) each other.
3. But, when the magnetic material was magnetized, all the molecules had been lined up so that all the north-seeking poles were facing one direction and all the south-seeking poles were facing the opposite direction.
4. This arrangement left free north-seeking poles at one end of the magnet and free south-seeking poles at the other end of the magnet.

B. This molecular theory of magnetism explained why the force of the magnet was strongest at the ends (where there were free poles) and weakest in the middle (where north-seeking and south-seeking poles were next to each other).

1. The theory also explained why a magnetized bar or rod, when cut in half, produced two new magnets even though the middle of the magnetized bar originally had little or no magnetic force.
2. Each of the two new magnets now had free north-seeking poles at one end and free south-seeking poles at the other end.

C. Today scientists believe that the magnetism of magnetic materials is due to the spinning movement of the electrons as they revolve or travel around the nucleus in the atom.

1. When the magnetic materials are not magnetized, some electrons spin in one direction while other electrons spin in the opposite direction, and in this way they neutralize each other.
2. When the magnetic materials are magnetized, the electrons are now made to spin in the same direction, making the atoms act like tiny magnets.

D. This newer theory does not really destroy the older theory, but rather it helps to improve it because molecules are made up of atoms.

VI. How Magnets Are Made

A. Only magnetic materials (iron, steel, cobalt, nickel) can be made into magnets.

B. It is possible to make temporary or permanent magnets.

C. Temporary magnets are made from soft iron.

1. Materials like soft iron are easy to magnetize, but they lose their magnetism just as easily.
2. Their molecules (or electrons) are easy to line up, but they lose their arrangement just as easily.

3. Nails, tacks, screws and bolts are made of soft iron.

D. One way of making a temporary magnet is to bring a magnetic material near a permanent magnet or have the magnetic material touch the permanent magnet.
1. The magnetic material now becomes a magnet, but only temporarily, because, as soon as the material is taken away from the permanent magnet and its magnetic field, the material loses its magnetism.
2. This way of making magnets is called **induction or induced magnetism.**

E. A second way of making a temporary magnet is to stroke a piece of soft iron (such as a nail) many times with a permanent magnet, but only in one direction.
1. Stroking only in one direction helps line up the molecules (or electrons) in the soft iron so that all the north-seeking poles are facing one direction and all the south-seeking poles are facing the opposite direction.
2. The soft iron is only a temporary magnet because the molecules (or electrons) soon lose their arrangement.

F. A third way of making a temporary magnet is to wrap an insulated wire many times around a piece of soft iron, and then connect the bare ends of the wire to the posts of a dry cell.
1. This kind of temporary magnet is called an **electromagnet.**
2. An electromagnet will stay a magnet only as long as the electric current flows from the dry cell through the wire.

G. Permanent magnets are made from steel.
1. Materials like hard steel are hard to magnetize, but their magnetism is more permanent because they do not lose their magnetism easily.
2. Their molecules (or electrons) are harder to line up, but once the lining up is done, it is just as hard to throw them out of line.
3. Needles, knives, scissors, and screw drivers are made of steel.

H. One way of making a permanent magnet is to stroke a piece of steel (such as a knitting needle) many times with a permanent magnet in one direction only.

I. A second way of making a permanent magnet is to use a piece of steel instead of soft iron in an electromagnet.

VII. How Magnets Can Lose Their Magnetism

A. There are three common ways in which magnets can be made to lose their magnetism.
1. By dropping or striking them.
2. By heating them.
3. By placing the north-seeking poles of two magnets side by side or on top of each other.

B. In each case the molecules (or electrons) will be disarranged and thrown out of line, and in this way neutralize each other.

C. There are two common ways of keeping magnets strong.
1. One way is to put a piece of soft iron, commonly called a **keeper,** across the poles of a horseshoe magnet or U-shaped magnet.
2. A second way is to store two bar magnets so that the north-seeking pole of one magnet is beside or on top of the south-seeking pole of the other magnet, and then place a keeper across the poles of both magnets.

VIII. The Earth Behaves as a Magnet

A. If a magnet is suspended so that it can swing freely, the magnet will move until it is in a north-south position, with the north-seeking pole of the magnet pointing to the north.

B. This movement occurs because the earth behaves as if it were a huge magnet, with a north magnetic pole, a south magnetic pole, and a magnetic field.

C. The north and south magnetic poles are not located at the same points as the north

and south geographic poles, but are slightly to one side.

D. A compass tells us where the direction north is because it contains a magnetized needle whose north-seeking pole is affected by the earth's magnetic field and points in the direction of the north magnetic pole.

E. A compass needle will always point to the north unless it is brought near magnetic materials or a magnet, which then affect its position.

F. Many persons are often confused because the pole of a free-swinging magnet marked "north" points to the north.

1. This apparent attraction of unlike poles occurs because the poles of a magnet were named north and south poles long before we knew that the earth acted as a huge magnet.
2. If we had known about the earth's magnetic field first, then most likely the pole of a magnet that points to the north would originally have been called the south pole, as it should have been.
3. To make this change now would be most confusing, so instead we use the term "north-seeking" and "south-seeking" for the poles of a magnet.

IX. The Uses of Magnets

A. Magnets can be used to pick up pins and needles, to keep cabinet and refrigerator doors closed, to hold the lids of cans after the can opener has removed them, and to hold pieces of paper and other objects to bulletin boards.

B. Magnets are also used in electric motors and generators, in compasses, and in many toys and games.

ELECTROMAGNETS

I. Magnetism Can Be Obtained from Electricity

A. When an electric current passes through a wire, there is a magnetic field around the wire.

B. When the wire carrying the electric current is placed over a compass, the compass needle turns away from its north-seeking position.

C. If the wire carrying the electric current is wound into a coil, the coil will act just like a magnet, with north- and south-seeking poles.

D. Placing a bar of soft iron in the center of the coil will increase the strength of this magnet greatly.

E. A magnet of this kind, made from electricity passing through a wire, is called an electromagnet.

II. How an Electromagnet Is Made

A. Three things are needed to make a strong electromagnet.

1. A bar of soft iron, such as a large iron nail, which is called the core.
2. A coil of insulated wire wrapped around the core.
3. A source of electric current, like that from a dry cell.

B. When the ends of the coil of wire are connected to the dry cell, the core and coil act like a magnet.

C. The magnetism will continue as long as an electric current passes through the coil.

D. When the ends of the coil are disconnected from the dry cell, the coil and core lose their magnetism.

E. Soft iron is almost always used as the core of an electromagnet because it magnetizes

easily and loses its magnetism just as easily.

F. The poles of an electromagnet can be determined very easily by bringing a compass near it.
   1. If the north-seeking part of the compass needle swings toward one end of the electromagnet, this end is the south-seeking pole of the electromagnet.
   2. If the north-seeking part of the compass needle swings away from one end of the electromagnet, this end is the north-seeking pole of the electromagnet.

G. When the connections of the wire to the dry cell or other source of electric current are reversed, the poles of the electromagnet are also reversed.

H. Commercial electromagnets use yards and yards of insulated wire, one or more very large cores, and a much stronger electric current.

III. Making Electromagnets Stronger

A. Increasing the number of turns of wire around the core will make an electromagnet stronger.

B. Increasing the strength of the electric current (using more dry cells) will make the electromagnet stronger.

C. If the number of turns of wire is doubled, or the strength of the current is doubled, the electromagnet will become twice as strong.

IV. How an Electromagnet Is Like a Permanent Magnet

A. An electromagnet has two poles: a north-seeking and a south-seeking pole.

B. An electromagnet has a magnetic field around it.

C. An electromagnet will attract magnetic materials like iron, steel, cobalt, and nickel.

D. The force of an electromagnet can pass through nonmagnetic materials, like glass and wood.

V. How an Electromagnet Differs from a Permanent Magnet

A. An electromagnet is a temporary magnet so that its magnetism can be turned on or off at will.

B. The poles of an electromagnet can be reversed.

C. The electromagnet can be made stronger or weaker.

D. An electromagnet usually has a soft iron core, but the permanent magnet is usually made of hard steel.

VI. Uses of Electromagnets

A. One of the early commercial uses of electromagnets was in the telegraph.

B. A simple telegraph circuit has four parts.
   1. A source of electric current, such as one or two dry cells.
   2. A key, which acts like a switch to turn the current on and off.
   3. A wire, which connects the parts of the telegraph circuit together.
   4. A sounder, which receives the electrical energy and converts it to sound.

C. The sounder has two parts.
   1. A U-shaped electromagnet, placed so that its poles are up in the air.
   2. A metal bar, called an armature, which is located above the poles of the electromagnet.

D. The telegraph operates as follows.
   1. When the key is pressed down, a current flows through the circuit and the electromagnet becomes magnetized.
   2. The electromagnet attracts the armature, which hits a metal screw below it and makes a clicking noise.
   3. When the key is released, the electric current stops flowing and the electromagnet loses its magnetism.
   4. The armature is no longer attracted, and a spring pulls it back into position again above the poles of the electromagnet.
   5. When the armature springs back, it hits

another metal screw above it and makes a second clicking noise.

6. By pressing the key down for a longer or shorter time, we can control the time between the clicks that are produced.
7. If the time between the clicks is short so that we get two clicks close together, we call the two clicks, a **dot.**
8. Two clicks farther apart are called a **dash.**
9. A code of dots and dashes, called the **Morse code,** is used to send messages by telegraph.
10. Combinations of dots and dashes are used to stand for letters of the alphabet and for numbers.

E. Electromagnets are used in other forms of communication, such as the telephone, radio, and television.

F. Electromagnets are used in industry in such devices as the motor, generator, transformer, and crane.

G. Electromagnets are found in the home in bells, buzzers, chimes, circuit breakers, some electric appliances, and in many electric toys.

STATIC ELECTRICITY

I. How Static Electricity Is Produced

A. Static electricity is produced by friction.

1. When two different materials, especially nonmetals, are rubbed together, they each attract light objects, such as small bits of paper and cotton thread, to them.
2. We say that these materials have become **electrically charged.**

B. The kind of electricity that has been produced in these objects does not move. It is called **static,** or stationary, electricity.

C. When electricity does move, it is now called **current** electricity.

II. The Nature of Static Electricity

A. All matter is made up of tiny particles called **atoms.**

B. Inside the atom are three even tinier particles: **protons, neutrons,** and **electrons.**

1. The protons and neutrons are much heavier than the electrons and are located in the center, or **nucleus,** of the atom.
2. The much lighter electrons are outside the nucleus and move rapidly around the nucleus.
3. The electrons move freely around the nucleus while the protons are packed closely together with the neutrons in the nucleus.
4. Each proton has a **positive** (+) electrical charge, and each electron has a **negative** (−) electrical charge.
5. The neutron is neither positively nor negatively charged. It is said to be **neutral.**

C. Ordinarily there are the same number of positively charged protons and negatively charged electrons in the atom.

1. As a result, the atom is electrically neutral.
2. The atom is neither positively nor negatively charged.

D. However, it is possible to remove electrons from the atoms in a material by rubbing the material with another material.

1. When two materials are rubbed together, electrons pass from one material to another.
2. The material that loses electrons now has more positively charged (+) protons than negatively charged (−) electrons, so this material becomes positively charged.
3. The material that gains electrons now has more negatively charged (−) elec-

trons than positively charged (+) protons, so this material becomes negatively charged.

E. Protons cannot be removed from the atom by rubbing. They are inside the nucleus and usually move only when the whole atom moves.

F. When a hard rubber rod is rubbed with a piece of wool or fur, some of the electrons are rubbed off the wool or fur and onto the rubber.
   1. The rubber has gained negative electrons. It now has more negative electrons than positive protons, so it becomes negatively charged.
   2. The wool or fur has lost negative electrons. It now has more positive protons than negative electrons, so it becomes positively charged.

G. When a glass rod is rubbed with a piece of silk, some of the electrons are rubbed off the glass and onto the silk.
   1. The glass has lost negative electrons and becomes positively charged because it now has more positive protons than negative electrons.
   2. The silk has gained negative electrons and becomes negatively charged because it now has more negative electrons than positive protons.

H. Materials will stay charged only as long as electrons have no way of entering or leaving the materials.

III. Law of Electrostatic Attraction and Repulsion

A. When two negatively charged materials are brought close to each other, they will be repelled and move away from each other.

B. The same thing will happen when two positively charged materials are brought close together.

C. But when a positively charged material is brought close to a negatively charged material, they will both be attracted and move closer to each other.

D. These behaviors can be stated as a law of electrostatic attraction and repulsion, as follows: the same kind of electrical charges will repel each other, but different kinds of electrical charges will attract each other.

IV. Why Electrically Charged Materials Attract Materials That Are Not Charged

A. Materials that are either positively or negatively charged will attract materials that are not charged.
   1. Materials that are not electrically charged are said to be neutral.
   2. Neutral materials have neither lost nor gained electrons.

B. When a negatively charged hard rubber rod is brought close to a small piece of paper, the paper is attracted to the rod.
   1. The negatively charged rubber rod repels electrons from the side of the paper nearest the rod.
   2. These electrons move to the other side of the paper, as far away from the rod as possible.
   3. The side of the paper nearest the rod is now positively charged because it has more positive protons than negative electrons, so it is attracted to the negatively charged rod.
   4. When the paper touches the rod, some of the excess electrons from the rod flow into the paper, and the entire piece of paper becomes negatively charged, too.
   5. The paper then drops off the rod because it now has the same electrical charge (negative) as the rod and is repelled.

C. When a positively charged glass rod is brought close to a small piece of paper, the paper is attracted to the rod.
   1. The positively charged rod attracts electrons, and they accumulate on the side of the paper nearest the rod.
   2. The side of the paper nearest the glass rod is now negatively charged because

it has more negative electrons than positive protons, so it is attracted to the positively charged rod.

3. When the paper touches the rod, some of the electrons from the paper flow into the rod, leaving the entire piece of paper positively charged, too.
4. The paper then drops off the rod because it now has the same electrical charge (positive) as the rod and is repelled.

V. CONDUCTORS AND NONCONDUCTORS

A. Some materials allow electrons to move or flow easily through them.
   1. These materials are called **conductors.**
   2. Current electricity is the rapid flow of electrons through a good conductor.
   3. Most metals are good conductors of electricity.
   4. Carbon, a nonmetal, can also conduct electricity.

B. Other materials will not let electrons flow easily through them.
   1. These materials are called **nonconductors, or insulators.**
   2. Some insulators are rubber, glass, wool, fur, plastics, wood, and dry air.

C. Static electricity works best with insulators because the electric charges that are produced remain on the insulators and do not leak away.

D. Static electricity is most easily produced in the winter, when it is very cold outside, and warm and dry inside.
   1. In the summer an invisible film of water forms on materials.
   2. This film lets the electric charges leak away almost as soon as they are formed, so it is very hard to give the materials an electric charge that will last.

VI. ELECTRIC SPARKS

A. Ordinarily electrons do not flow very easily through the air because the air is an insulator.

B. Under certain conditions, however, electrons can be made to flow through the air.
   1. This flow may occur when a highly charged material is brought near an oppositely charged material, or even a neutral material.
   2. The electrostatic force of attraction between the positively and negatively charged materials is very great.
   3. If the force of attraction becomes great enough, the resistance of the air to a flow of electrons breaks down, and a flow of electrons takes place between the two materials.

C. This rapid movement of electrons through the air appears as a **spark,** and is actually a flow of **current electricity.**

VII. LIGHTNING AND THUNDER

A. **Lightning** is a huge electric spark produced by static electricity.

B. During thunderstorms rapidly rising or falling air currents may rub against the rain clouds.
   1. This rubbing will produce very large and strong electrical charges in the clouds.
   2. Sometimes one part of the cloud will become positively charged and the other part will become negatively charged.
   3. Sometimes a cloud will be ripped into two parts by the rapidly moving air, producing two new clouds, each with a different electrical charge.

C. When a negatively charged cloud comes close to the earth's surface, the electrons in the earth's surface will be repelled into the earth, leaving the surface positively charged.

D. When a positively charged cloud comes close to the earth's surface, the electrons in the earth will be attracted to the surface, leaving the surface negatively charged.

E. Lightning is the huge spark produced when electrons leap suddenly from the following places:
   1. One charged part of a cloud to another.

2. One charged cloud to another of opposite charge.
3. A charged cloud to the earth.
4. The earth to a charged cloud.

F. When lightning strikes the earth, it usually strikes an object, such as a tall tree, that is the highest point on the earth's surface.
1. Lightning strikes this object because electrons flow more easily through solid objects than through a gas like air.
2. Therefore, it is a good idea to keep away from trees or other tall objects during a thunderstorm.

G. **Lightning rods** are used to protect buildings from damage by lightning.
1. The lightning rod is made of a metal such as copper, which is a good conductor of electricity.
2. The lightning rod's highest point is kept higher than the building so that the lightning will be attracted to the rod and not the building.
3. The lowest point of the rod goes deeply into the ground so that the lightning can be conducted quickly and harmlessly to the ground.

H. As the lightning passes through the air, the air becomes very hot and expands suddenly.
1. This expansion of the heated air sets up giant vibrations and produces the sound we know as **thunder.**
2. We see the lightning first and then hear the thunder because light travels much faster than sound.
3. Because it takes longer for the sound to travel from the farther end of the lightning than from the nearest end, we hear the thunder as a long rolling sound.
4. Also, the sound of thunder may be reflected from cloud to cloud, producing echoes that add to the rolling effect.

VIII. Other Common Occurrences of Static Electricity

A. Scuffing, or even just walking across a rug on a very cold day, when it is warm and dry inside, will produce a shock or a spark when your finger touches a metal object.
1. The body picks up negative electrons through the shoes and releases these electrons upon contact with the metal object.
2. The same thing happens when you slide your body across the nylon seat of a car and touch the door handle.

B. Combing your dry hair with a rubber comb will charge the hair and make it stand on end.
1. The comb removes electrons from the hair, leaving the hair positively charged.
2. Because each strand of hair has the same positive charge, they all repel one another and your hair tends to stand on end.
3. The same thing happens when you stroke a cat's fur.

C. Nylon sweaters and undergarments will become charged as they rub against your body, and will crackle and spark when they are removed.

D. Trucks containing gasoline and other flammable liquids can build up a large electric charge as the liquid sloshes inside the tank.
1. If there were no way to stop the charge from building up, a spark might be produced that would make the gasoline explode.
2. This building up of an electric charge is prevented by attaching a metal chain to the tank and letting the chain dangle to the ground.
3. As soon as an electric charge is formed in the tank, the charge is allowed to escape through the chain and into the ground.

E. Even the tires of trucks and passenger cars will produce an electric charge in the car as the tires rub against the road when they are moving.
1. Some cars have strips containing metal running from the body of the car to the ground so that the charge may escape.

2. At toll booths a flexible upright metal rod touches the car first and lets the charge escape so that both the attendant and the person paying the toll will not receive a shock when their hands touch.

CURRENT ELECTRICITY

I. The Nature of Current Electricity

A. Scientists do not know exactly what electricity is.

B. The word *electricity* is used to describe a flow of electrons.

1. All matter is made up of tiny particles called **atoms.**
2. Inside the atom are three even tinier particles: **protons, neutrons,** and **electrons.**
3. The protons and neutrons are much heavier than the electrons and are located in the center, or **nucleus,** of the atom.
4. The much lighter electrons are outside the nucleus and move rapidly around the nucleus.
5. The electrons move freely around the nucleus while the protons are packed closely together with the neutrons in the nucleus.
6. Each electron is **negatively charged** and is thought to be a particle of negative electricity.
7. Each proton is **positively charged** and is thought to be a particle of positive electricity.
8. The neutron is a **neutral** particle. It is neither positively charged nor negatively charged.
9. Ordinarily an atom has the same number of electrons and protons, so it is electrically neutral.

C. Scientists think that when an electric current is flowing through a material the electrons move from atom to atom inside the material.

II. The Simple Electric Circuit

A. There are three parts to a simple electric circuit.

1. A source of electricity, such as a dry cell or electric generator.
2. A path along which the electric current can travel, such as a copper wire.
3. An appliance that uses the electricity, such as a bell or a light bulb.

B. In an electric circuit the electric current flows from the source of electricity along one path to the appliance, passes through the appliance, and then returns through a second path to the source of electricity.

C. When all three parts of the circuit are connected so that an electric current is flowing, the circuit is said to be **completed** or **closed.**

D. When any of the three parts of the circuit are disconnected so that an electric current is not flowing, the circuit is said to be **incomplete** or **open.**

III. Conductors and Nonconductors

A. Some materials allow an electric current to flow through them easily.

1. Such materials are called **conductors.**
2. The atoms in a good conductor of electricity do not have a very tight hold on some of their electrons so that these electrons can flow freely through the material.
3. Most metals are good conductors of electricity. Examples of metals that are good conductors include copper, silver, aluminum, iron, and zinc.

4. Carbon, although a nonmetal, can also conduct electricity.
5. When certain chemicals, known as acids, bases, and salts, are dissolved in water, the solutions will conduct an electric current.

B. Materials that do not allow an electric current to flow through them easily, if at all, are called **nonconductors** or **insulators.**

1. The atoms in a nonconductor of electricity have such a tight hold on their electrons that few, if any, flow through the material.
2. Examples of insulators (nonconductors) are paper, wood, glass, porcelain, cloth, dry air, rubber, and many plastics.

C. Whenever it is necessary, conductors are covered with or supported by insulators.

1. The insulators protect you from receiving an electric shock if you should happen to touch the conductor.
2. Insulators also prevent the electric current from leaving the conductor and taking an unwanted path.

D. Pure water itself is a nonconductor of electricity.

1. But water will make many insulators become good conductors when they are wet.
2. Thus, it is a good and safe practice not to touch electric appliances or wires when your hands are wet or if you are standing on a wet bathroom floor.

IV. Switches

A. Electricity is turned on or off by **switches.**

B. Switches are devices that make it easy and convenient to close or open an electric circuit.

1. When the switch is turned or pushed one way, it will complete the electric circuit and the electric current will flow.
2. When the switch is turned or pushed the opposite way, it will open or "break" the circuit and the electric current stops flowing.

C. Three common kinds of switches are the **knife, pushbutton,** and **snap** switch.

1. The knife switch has a metallic, movable blade that moves in and out of metallic "jaws" to close or open an electric circuit.
2. The pushbutton switch, which is used with door bells, has a flat, coillike spring that pushes forward to close the circuit and flies back to open the circuit.
3. The snap switch, which is used on walls, moves one way to close the circuit and the opposite way to open the circuit.

V. Series and Parallel Circuits

A. If more than one dry cell is used in an electric circuit, the dry cells are usually connected in series.

1. When dry cells are connected in **series,** the wires run from the outside, or negative, terminal of one cell to the center, or positive, terminal of another cell.
2. Connecting dry cells in series will increase the amount of electrical force or power produced.

B. Appliances in an electric circuit may be connected either in series or in parallel.

C. When appliances in an electric circuit are connected in **series,** all the electric current flows **through** each appliance, one after the other, when the circuit is closed.

1. If one appliance fails to function, or is turned off, the other appliances stop functioning because the circuit has been broken.
2. A good example of appliances connected in series is the single strand set of Christmas tree lights.
3. If one light goes out in this set of lights, the circuit is broken and all the lights go out.
4. Because all the electricity flows through each light, the more lights that are added, the more resistance the electricity meets, and the less current there is to flow through the lamps.

5. Because the brightness of the lights depends upon the amount of current flowing through them, the lights will become dimmer.

D. When appliances in an electric circuit are connected in **parallel**, the electric current flows across each appliance.

1. The appliances are connected in such a way that the electric current **branches off**, and only part of the current goes through each appliance.
2. Now each appliance can operate independently of the other so that, if one appliance fails to function, the circuit is not broken and the other appliances continue to function.
3. The electric current flowing through each appliance is completely separate from the current flowing through the other appliances.
4. A good example of appliances connected in parallel is the double strand set of Christmas tree lights.
5. If one light goes out in this set of lights, there is still a complete circuit through the rest of the lights and they all stay on.
6. Since the electricity flowing through each light is separate from the electricity flowing through all the other lights, the addition of more lights to the set will not affect their brightness.

E. All house circuits are wired in parallel so that the lights and other appliances can all be turned on and off separately, without breaking the circuit.

F. In most houses the main circuit has at least two branches, connected in parallel, which carry electricity to appliances in different parts of the house.

VI. Overloading an Electric Circuit

A. Whenever there is a flow of electrons (electric current) in a wire, heat is produced.

B. This heat is formed because the metal of the wire opposes the flow of electrons through the wire.

C. The more current there is flowing through a wire, the hotter the wire will become.

D. In a house each branch circuit is designed to carry only so much current.

E. As appliances are connected into the circuit, each uses a certain amount of current.

F. If too many appliances are connected into a circuit at one time, the circuit will become overloaded.

1. The combined current needed by all the appliances may be more than what the circuit can carry.
2. This large amount of current may make the wires so hot that they will burn away the insulation and even start a fire.

G. Another way of overloading a circuit is to have a **short circuit** happen.

1. Electricity will always take the shortest and easiest path back to its source.
2. When the insulation on the wires of an electric circuit wears off and exposes the bare wires, a short circuit will take place if the bare wires touch.
3. When the bare wires touch, the electric current will take a short cut, or circuit, back to its source without first flowing through an appliance that will use the electrical energy.
4. A large amount of electricity will now flow quickly through the wires, making them very hot.

H. **Fuses** and **circuit breakers** are safety devices used to prevent the wires from becoming too hot when an overload takes place.

1. They are connected in series with the circuit so that the current must pass through them on its way to the appliances.
2. They act like emergency switches to open the circuit if too much current is flowing through it.

I. A fuse contains a strip of metal that will melt easily when heated.

1. The metal melts more easily than the wires in a circuit.
2. When a circuit becomes overloaded, either because of too many appliances in

the circuit or because of a short circuit, the wires become very hot.

3. But the metal strip in the fuse also becomes hot and melts, or "blows," before the wires do, thus breaking the circuit before any damage can be done.
4. The fuse is usually enclosed in a tube or socket to prevent the melted metal from spattering and causing a fire.
5. No current will flow through the circuit until the blown fuse is replaced.

J. A circuit breaker has a bar, made up of two strips of metal connected together.

1. One metal strip will expand more than the other strip, when heated, causing the bar to curve.
2. When a normal amount of electric current flows through the circuit and the circuit breaker, the bar remains flat and keeps the circuit closed.
3. When there is an overload, the bar becomes hot and begins to curve, and opens the circuit.
4. The circuit breaker does not need to be replaced, but can be pushed back into place after the cause of the overloading is removed.

VII. Electrical Units of Measure

A. The **volt** is the unit of electrical pressure. It is a measure of the force pushing the electrons through a conductor and overcoming the resistance of the conductor.

B. The **ampere** is the unit of the rate of flow of the electric current. It is a measure of the number of electrons flowing per second, or the intensity of the current.

C. The **ohm** is the unit of electrical resistance. It is a measure of the resistance a conductor offers to the flow of electric current.

D. There is a relationship between electrical pressure, rate of flow of current, and electrical resistance.

1. The greater the electrical pressure (number of volts), the greater the current (number of amperes) will be, and vice-versa.
2. The greater the electrical resistance (number of ohms), the smaller the current (number of amperes) will be, and vice-versa.
3. This relationship, called **Ohm's law**, can be expressed as follows:

$$\text{Amount of Current} = \frac{\text{Electrical pressure}}{\text{Electrical resistance}}$$

4. Ohm's law is more commonly stated in electrical units, as follows:

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

E. The **watt** is the unit of electrical power.

1. It is the measure of the rate, or how fast, electrical energy is being used.
2. Watts can be found by multiplying the number of volts by the number of amperes.

F. The **watt-hour** is the unit of electrical energy.

1. It is the amount of energy used at the rate of one watt for one hour.
2. When we pay for electrical energy we pay by the **kilowatt-hour.**
3. A kilowatt is 1000 watts.

VIII. Sources of Electricity

A. Electricity can be obtained in several different ways.

B. Electricity is a form of energy and therefore can be produced from other forms of energy.

C. The following forms of energy can be changed, or transformed, into electrical energy.

1. **Chemical** energy, using the wet cell, dry cell, and storage battery.
2. **Mechanical** energy, using the generator and the piezoelectric cell.
3. **Light** energy, using the photoelectric cell and the solar battery.
4. **Heat** energy, using the thermocouple.

IX. The Wet Cell

A. The **wet cell**, also known as the **voltaic cell**, consists of two different metals placed in a chemical solution that will conduct an electric current.
   1. The metals that are selected must be such that one of them will react faster with the solution than the other metal will.
   2. When the metals are in the solution they must be kept apart.
   3. A solution of an acid, a base, or a salt in water will be able to conduct an electric current.

B. A commonly used wet cell is made by inserting a strip of zinc and a strip of copper partially in a glass of water containing a little sulfuric acid.

C. The sulfuric acid acts chemically on the atoms of zinc and dissolves the zinc, leaving many electrons behind on the zinc that remains.
   1. As the negative electrons accumulate on the zinc, the strip becomes negatively charged.
   2. The zinc strip is called the **negative pole** of the cell.

D. At the same time the copper strip loses electrons to the sulfuric acid.
   1. The copper strip now becomes positively charged because it has lost negative electrons.
   2. The copper strip is called the **positive pole** of the cell.

E. In this way an **electrical pressure** is built up between the two strips.

F. When a wire is connected to the dry ends of the strips, there is a flow of electrons from the negatively charged zinc to the positively charged copper, and an electric current has been produced.

G. The electric current flows in one direction only, from the zinc to the copper, and is called **direct current (DC)**.

H. The electricity obtained by the chemical action in a wet cell can be used to light a bulb or ring a bell.

X. The Dry Cell

A. The **dry cell** is a more convenient form of wet cell.

B. The materials are placed in a sealed container so that nothing can spill when the dry cell is carried or tipped.

C. A dry cell is not really dry.
   1. The chemicals inside must be kept moist.
   2. If the inside of the dry cell becomes dry, the cell will no longer operate.

D. Dry cells come in many sizes and shapes, but they all are made the same.
   1. There is a zinc can, which serves as the negative pole and also as a container for the rest of the chemicals in the cell.
   2. Instead of copper, a carbon rod in the middle of the can serves as the positive pole.
   3. The can is then filled with a wet paste made up of a solution of ammonium chloride and zinc chloride, mixed with particles of manganese dioxide and powdered carbon.
   4. Blotting paper soaked in ammonium chloride solution lines the inside of the zinc can to help keep the chemicals moist longer.
   5. The top of the zinc can is covered with a layer of sealing wax or pitch to make the dry cell leakproof.
   6. Metal posts, or terminals, are located on top of the can: one post is attached to the carbon rod, the other to one end of the zinc can.
   7. An outside cover, usually cardboard, protects the can.

E. The chemical action inside the dry cell is very much like that of the wet cell.
   1. The zinc reacts with the moist ammonium chloride and accumulates electrons, becoming negatively charged.
   2. The carbon rod loses electrons and becomes positively charged.
   3. An electrical pressure is built up between the zinc and the carbon.
   4. When a wire is connected to the two terminals on top of the dry cell, an

electric current flows from the zinc to the copper terminal.

F. No matter how large or small a dry cell is, it has an electrical pressure of about 1½ volts.

G. The larger the dry cell, the longer it will last, but the electrical pressure will still be the same 1½ volts.

H. Dry cells cannot give a large steady electric current for a long time.

I. Dry cells are used in flashlights, portable radios, and doorbell circuits.

XI. The Storage Battery

A. The common **storage battery** produces electricity, just as the wet and dry cells do, from chemical energy.

B. The cell of a storage battery contains lead as the negative pole, lead peroxide as the positive pole, and a solution of sulfuric acid.

C. When the two poles are connected, an electric current will flow.

D. When the storage battery is used, both the lead and lead peroxide poles become covered with a chemical called lead sulfate.

E. When the poles are sufficiently covered with this lead sulfate, the storage battery will not operate, and we say that it has lost its charge.

F. But the storage battery is different from the wet and dry cell because it can be recharged and used again.

1. The poles of the storage battery can be connected to a source of direct electric current, which changes the lead sulfate on the poles back into lead and lead peroxide.
2. In this way electrical energy is used to give back the storage battery its chemical energy.
3. By recharging, the storage battery can be used again and again, each time using a source of direct electric current to get back the chemical energy that the battery had used up.

G. A storage battery usually contains three or six cells, connected in series.

1. Each cell has an electrical pressure of 2 volts.
2. Each cell adds its voltage to the others, so we get 6-volt or 12-volt batteries.

H. The most common use of the storage battery is in the automobile to start the motor and to run many small electrical appliances in the car.

I. A storage battery can also be recharged while the car is running.

1. Every car has a **generator**, which is a machine for producing electricity.
2. The generator is driven by the motor of the car.
3. When the car is running, the electricity produced by the generator flows into the storage battery and recharges it.
4. In this way the generator gives the battery back the electrical energy that was used to start the car and run the appliances.

XII. The Generator

A. The **generator** produces electricity from mechanical energy.

B. When a wire is moved up and down between the poles of a horseshoe or U-shaped magnet so that the wire cuts across the lines of force in the magnetic field, an electric current is produced.

1. The electric current can be detected by connecting the ends of the wire to the terminals of a sensitive instrument, called a **galvanometer**, which is used to measure or detect weak electric currents.
2. When the wire is moved down, the needle of the galvanometer moves in one direction; when the wire is moved up, the needle moves in the opposite direction.
3. The movement of the needle shows that the electric current that is produced changes direction.

C. This kind of current is called **alternating current** (AC) because it alternates by first

flowing in one direction, then in the opposite direction.

D. An alternating electric current will also be produced if the wire is held stationary and the magnet is moved.

E. If the wire or the magnet do not move, no current is produced.

F. Thus the mechanical energy of motion that is needed to move the wire or the magnet is changed to electrical energy by means of magnetism.

G. A generator is just a machine used to make wires cut lines of force very quickly.

H. A simple alternating current generator has four necessary parts.

1. A **coil** of many turns of wire, called an **armature.**
2. A **U-shaped magnet,** with the armature placed between the poles of the magnet.
3. Two **metal rings,** called **slip rings,** each connected to an end of the coil to collect the current produced in the armature.
4. **Brushes,** made of metal or carbon, to lead the current out of the generator.

I. With small generators and many large generators, the coil moves and the magnet remains stationary.

J. With some large generators, the magnet moves and the coil remains stationary.

K. The amount of current produced by a generator depends upon how many lines of force are cut and on how quickly they are cut.

L. There are several ways of increasing the number of lines of force to be cut:

1. Using more magnets.
2. Making the magnets stronger by using electromagnets instead of permanent magnets.
3. Using more turns of wire in the coil of wire.
4. Inserting an iron core inside the coil.

M. Increasing the speed with which the lines of force are cut can be done by moving either the coil or the magnet faster.

N. At large electric power stations falling water or steam is used to turn large wheels, called **turbines,** which turn the coils or magnets of the generator and produce electric current.

O. Trains and ships burn fuel to run engines or turbines, which operate generators that supply the electricity needed to drive the wheels or propellers.

P. The alternating electric current produced at power plants has a high electrical pressure or voltage.

1. This high electrical pressure is necessary to send the electricity over long distances and overcome the resistance of miles and miles of wire.
2. Sometimes the electrical pressure in the wires amounts to several thousand volts.
3. But appliances in the home use only 110 volts, and several thousand volts in the home would be dangerous.
4. Just before the wires that branch off the main wires enter the home, the high voltage is stepped down to 110 volts by a device called a **transformer.**
5. Transformers are voltage changers. They can either step down or step up the voltage, as needed.

Q. Alternating current changes its direction many times each second.

1. Two changes in direction are called a **cycle.**
2. In the home a 60-cycle alternating current is used.
3. This means that in 1 second the current flows 60 times in one direction and 60 times in the opposite direction.

R. Sometimes generators are needed that will produce direct current instead of alternating current.

1. Direct current is needed for long periods of time to charge storage batteries and put metal plate on materials.
2. To produce direct current a generator uses a **commutator** instead of slip rings.
3. The commutator is a single ring that is split in half.
4. The commutator automatically reverses

the flow of alternating current just as the current changes direction.

5. As a result, the current flows only in one direction and so becomes a direct current.

XIII. The Piezoelectric Cell

A. The **piezoelectric cell** is another way of producing electrical energy from mechanical energy.

B. When certain crystals like quartz and Rochelle salt are squeezed mechanically, an electric current is produced.

C. Piezoelectric cells containing such crystals are used in the arms of some record players to "pick up" the sound as the needle moves along the groove of the record.

XIV. The Photoelectric Cell

A. Certain metals, like potassium and selenium, are sensitive to light.

B. When light strikes such a metal, electrons flow from the metal and produce a weak electric current.

C. The stronger the light, the stronger the electric current.

D. The **photoelectric cell** contains this light-sensitive metal and is able to change light energy into electrical energy.

E. Photoelectric cells are used in camera light meters to control the amount of light that enters the camera.

1. When the light is strong, the photoelectric cell makes the shutter cut down the amount of light that is entering the camera.
2. When the light is weak, the photoelectric cell makes the shutter open wider, so that more light can enter the camera.

F. The electricity produced from photoelectric cells is also used to open doors and operate burglar alarms.

XV. The Solar Battery

A. The **solar battery** is a recent invention of scientists to produce electricity from sunlight.

B. The solar battery has in it many plates made from pure silicon.

C. When the plates are exposed to sunlight, an electric current is produced.

D. The solar battery is still being tested and promises to be valuable because it needs no chemical other than the silicon and there are no parts to wear out.

XVI. The Thermocouple

A. The **thermocouple** makes it possible to change heat energy into electrical energy.

B. A thermocouple can be made by twisting together one end of two wires of different metals and heating the twisted ends.

C. When the free ends of the metal wires are connected to a galvanometer, the needle of the galvanometer moves, showing that a weak electric current has been produced.

D. Thermocouples are being used as delicate thermometers to measure very small differences in temperature.

XVII. Uses of Electricity

A. Electricity can be used to produce heat.

1. Every electrical heating appliance has a conductor that gets hot when an electric current flows through it.
2. The conductor can be a coil of wire or a solid rod.
3. The heat is produced by the resistance that the conductor offers to the flow of electricity through it.
4. The greater the resistance, the hotter the conductor becomes.
5. The resistance can be increased either by making the wires thin or by using a material, such as nichrome metal, that

has a high resistance to the flow of electric current.

6. Also, the larger the electric current, the hotter the conductor becomes.
7. Electrical appliances that produce heat include toasters, irons, coffee percolators, hot plates, roasters, stoves, water heaters, and blankets.

B. Electricity can be used to produce light.

1. If a conductor becomes hot enough, it will give off light.
2. The filament of wire in a light bulb is long and thin.
3. The filament offers so much resistance to the flow of electric current that the filament becomes hot enough to give off a bright light.
4. Neon lights do not have a filament, but are filled with neon gas instead.
5. When an electric current of high voltage is sent through the neon gas in the tube, the gas glows with a red color.
6. Other gases and colored glass can be used to produce different colors.
7. In the fluorescent bulb, or tube, the light is produced by minerals that glow when invisible ultraviolet light strikes them.
8. The ultraviolet light is produced by sending an electric current of high voltage through a small amount of mercury vapor (gas) that is in the tube.
9. The ultraviolet light strikes the coating of minerals on the inside of the glass tube and makes them glow.

C. Electricity can be used to produce motion and power.

1. Electricity is used to run motors.
2. The parts of a motor are exactly the same as the parts of a direct current (DC) generator.
3. A motor has an armature, magnet, a commutator, and brushes.
4. The generator changes mechanical energy to electrical energy; the motor changes electrical energy to mechanical energy.
5. The generator uses magnetism to produce electricity; the motor uses electricity to produce magnetism.
6. The motor makes use of the law of attraction between unlike poles and of repulsion between like poles of magnets to make the armature move.
7. When an electric current passes from the brushes and commutator into the armature of a motor, the armature becomes an electromagnet.
8. The north-seeking pole of the electromagnetic armature is attracted by the south-seeking pole of the permanent magnet, and the south-seeking pole of the electromagnet is attracted by the north-seeking pole of the permanent magnet, so the electromagnetic armature moves.
9. As the armature turns, it reaches a position where the unlike poles of the armature and the permanent magnet face each other.
10. At this point the commutator reverses the direction of the current flowing into the electromagnetic armature, which automatically reverses the poles of the electromagnetic armature.
11. Now we have like poles of the armature and the permanent magnet facing each other.
12. These like poles repel each other and the armature moves again.
13. As a result, we get continuous motion of the armature, due to first the attraction of unlike poles and then the repulsion of like poles.
14. The commutator keeps reversing the current regularly to change the poles of the electromagnetic armature.
15. The power of a motor can be increased by making the magnetic fields of the armature and the permanent magnets stronger.
16. The magnetic field of the armature can be increased by using more turns of wire around the core and by sending more current through the armature.
17. The magnetic field of the permanent

magnet can be increased by using more magnets and by converting the permanent magnets to electromagnets.

18. Some motors are built to run on alternating current only.
19. Others run on direct current only.
20. Still others can run on either alternating or direct current, and are called universal motors.
21. There are so many uses for motors that it would be impossible to keep our present way of living without them.

D. Electricity can be used to plate metals.

1. Using electricity, metals can be coated, or plated, with other metals.
2. This process is called **electroplating.**
3. Only direct current can be used for electroplating.
4. To copper plate an object, the object to be plated and a bar of copper are placed in a solution containing a chemical called copper sulfate.
5. This arrangement is very much like the wet cell, except that in the wet cell a chemical action produces electricity, whereas in electroplating electricity produces a chemical action.
6. The object and the bar of copper are connected to a source of direct current.
7. The object to be plated acts as the negative pole, and is connected to the negative terminal, or connection, of the source of direct current.
8. The copper bar acts as the positive pole, and is connected to the positive terminal, or connection, of the source of direct current.
9. When a direct current flows, the copper in the solution is plated on the object.
10. At the same time, copper from the bar replaces the copper in the solution.
11. The longer the current flows, and the stronger the electric current used, the thicker the plate becomes.
12. Electroplating is used to plate silverware and to put chromium on automobile bumpers, grills, and other trimmings.

E. Electricity is used in many forms of communication, such as the telegraph, telephone, radio, television, and motion pictures.

XVIII. Safety Rules for Electricity

A. Disconnect all electrical appliances, especially heating appliances, when they are not being used.

B. Never touch a switch or electrical appliance when your hands are wet.

C. Never touch a switch, electrical appliance, radio, or telephone set when you are in the bathtub.

D. Make sure the switch is turned off whenever you disconnect or connect an electrical appliance.

E. Do not overload your home circuit by plugging too many appliances in one wall plug.

F. Never touch a bare wire that is carrying an electric current.

G. Never poke around the back of a radio or television set when these appliances are turned on.

H. Never put your finger into an open electric socket.

I. Replace electric cords where the insulation is cracked or worn thin.

J. Never touch an electric cord with wet hands.

K. Do not touch an electric cord with one hand and a water pipe, faucet, or radiator with the other hand.

L. When a fuse "blows," always replace the fuse with a new one that will carry the same amount of current.

M. When a fuse "blows," first find out what made it "blow" and correct the condition before putting in a new fuse.

N. Never put a penny in the fuse box instead of a new fuse.

LEARNING ACTIVITIES FOR "MAGNETISM AND ELECTRICITY"

MAGNETISM

1. *Determine what materials a magnet will attract* · Have the children collect a variety of materials, such as tacks, nails, paper clips, pins, needles, coins, rubber bands, pebbles, sand, and small pieces of chalk, crayon, wood, paper, glass, cloth, leather, and aluminum foil. Let the children try to pick up or attract each object with a magnet. Put to one side all those objects that are attracted by the magnet, and note that these objects are all made of iron or steel.

Point out that cobalt and nickel are also attracted by magnets. If the children comment that the American coin, the nickel, was not attracted by the magnet, explain that American nickels have mostly copper in them. Canadian nickels have much more nickel metal in them and will be attracted by the magnet.

2. *The attraction of a magnet is strongest at its poles* · Make a pile of tacks or iron filings. A shaker jar of iron filings can be obtained from a scientific supply house, or you can make your own filings by cutting up fine steel wool into very small pieces with a scissors. Now try picking up the tacks or filings with a bar magnet, using different parts of the magnet each time. The tacks or filings will be attracted most strongly to the poles of the magnet. Repeat the activity, using a horseshoe and a U-shaped magnet.

3. *A lodestone is a natural magnet* · Obtain a lodestone and a shaker jar of iron filings from a scientific supply house. You can make your own iron filings by cutting up fine steel wool into very small pieces with a scissors. Dip the lodestone into a pile of iron filings. The filings will cling in bunches at the various poles of the lodestone. Count the number of poles in the lodestone. There should be an even number, with just as many north-seeking as south-seeking poles.

4. *The law of magnetic attraction* · Allow a bar magnet to swing freely by cradling it in a piece of copper wire and connecting the wire with string to a ruler inserted into a pile of books (Figure 21–1). Bring the north-seeking

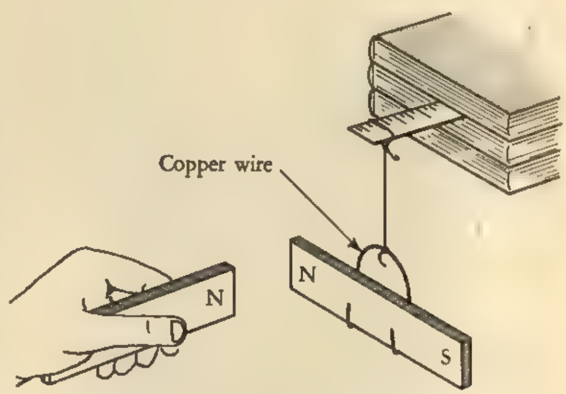


FIGURE 21–1.
LIKE POLES REPEL EACH OTHER, AND UNLIKE POLES ATTRACT EACH OTHER.

pole of another magnet near the north-seeking pole of the suspended magnet. Bring the two south-seeking poles together. Now bring the north-seeking pole of the magnet in your hand near the south-seeking pole of the suspended magnet. Note that like poles repel each other and unlike poles attract each other.

5. *Show magnetic fields and lines of force* · Place a sheet of cardboard or window glass over a bar magnet. Sprinkle iron filings or tiny bits of cut-up steel wool all over the cardboard, and then tap the cardboard gently a few times (Figure 21–2). The filings will rearrange them-

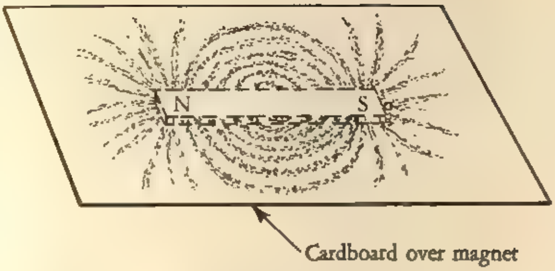


FIGURE 21–2.
LINES OF FORCE IN A MAGNETIC FIELD.

selves to form a definite pattern, showing the magnetic field and the lines of force located within the field. Note how the lines of force are concentrated at the poles.

Repeat the activity, using two bar magnets with the north-seeking pole of one bar magnet about 2 inches away from the south-seeking pole of the other bar magnet (Figure 21–3). Note how the lines of force seem to attract each other. Repeat the activity, this time placing two like poles near each other. The lines of force show the repulsion between like poles.

6. *Magnets can attract through nonmagnetic materials* · Place a sheet of cardboard on top of two poles of books placed a few inches apart.

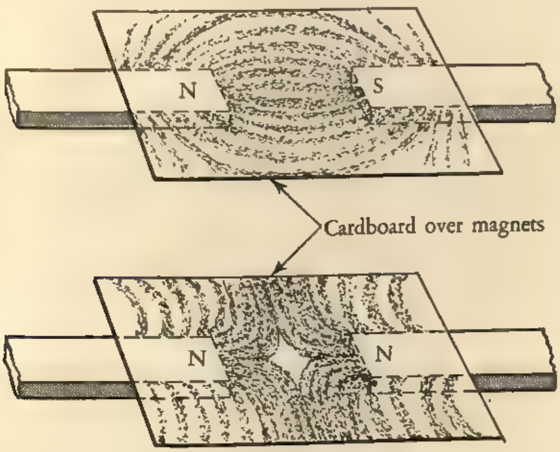


FIGURE 21–3.
LINES OF FORCE BETWEEN UNLIKE AND LIKE POLES.

Put some thumb tacks on the cardboard, and then slide a magnet along the underside of the cardboard (Figure 21–4). The magnet will attract the tacks and make them move. Repeat the activity, using sheets of glass, wood, aluminum foil, and cloth. Now use a sheet or iron, cut from a large "tin" can with tin snips. The tacks will not move because the force of the magnet passes into the iron, making it a magnet that attracts the tacks and holds them fast.

7. *A compass needle is a small magnet* · Examine a compass. The end of the compass

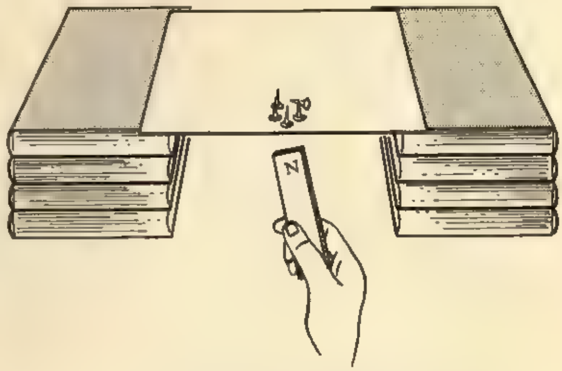


FIGURE 21–4.
THE FORCE OF A MAGNET PASSES THROUGH NON-MAGNETIC MATERIALS.

needle that points to the north is usually colored blue or black and is called the north-seeking pole. Bring the north-seeking pole of a bar magnet near the compass. The north-seeking pole of the compass needle will be repelled while the south-seeking pole of the needle will be attracted. Point out that a compass needle can be used to determine the poles of an unmarked magnet.

8. *The nature of magnetism* · Fill a test tube about two-thirds full of iron filings and stopper it. Stroke the test tube from end to end with one pole of a strong bar magnet about 20 times. Stroke slowly and gently in one direction only, being sure to lift your hand up in the air before coming down for another stroke. The test tube

will now act like a magnet because you have lined up all the filings so that they behave just as the molecules in them would behave, with their north-seeking poles pointing in one direction and their south-seeking poles pointing in the opposite direction. Bring a compass near the test tube and determine the poles of this test-tube magnet (see Learning Activity 7 above).

Now shake the test tube vigorously for some time, and then test with the compass again. Mixing up the filings causes the test tube to lose its behavior as a magnet.

9. *Make a temporary magnet by induction* · Plunge one pole of a bar magnet into a pile of small tacks, and then lift up the magnet. There will be a cluster of tacks around the pole. Each tack becomes a magnet by induction and attracts other tacks. Note that this induced magnetism is temporary because as soon as the bar magnet is taken away, the tacks do not attract each other any more.

Hold a large iron nail or spike quite close to one pole of a strong bar magnet. Keeping the nail and magnet in this position, dip the nail into a pile of small tacks, and then lift up the nail (Figure 21–5). The nail has been magnetized by induction, without even touching the magnet, and attracts the tacks. The tacks in turn are also magnetized by induction. When the bar magnet is removed, the nail loses its magnetism and the tacks fall off.

10. *Make a temporary magnet by stroking* · Stroke a large iron nail or spike from end to end with one pole of a strong bar magnet about 20 times. Stroke slowly and gently **in one direction only**, being sure to lift your hand up in the air before coming down for another stroke (Figure 21–6). The nail will become a magnet and pick up iron filings or tacks. Set the nail aside for 3 to 4 days. Because the nail is made of soft iron, it will have lost most of its magnetism and it will pick up very few filings or tacks.

11. *Make a temporary magnet with electricity* · Obtain some insulated copper bell wire (No. 18) from the hardware store. Wind this wire in a coil around a large iron nail or spike about 15 to 20 times. Remove the insulation from both ends of the wire, connect one

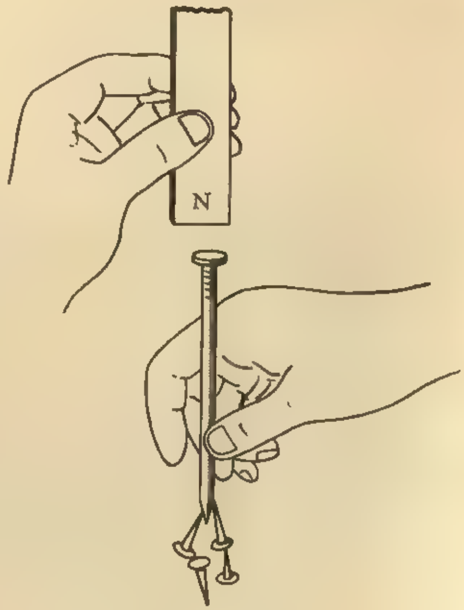


FIGURE 21–5.
THE NAIL ATTRACTS THE TACKS BECAUSE OF INDUCED MAGNETISM

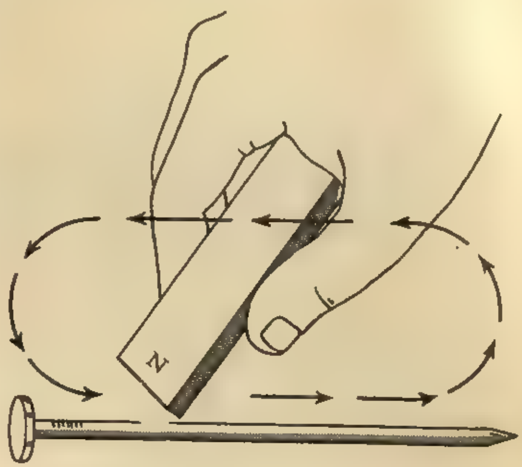


FIGURE 21–6.
THE NAIL BECOMES A TEMPORARY MAGNET WHEN STROKED WITH ONE POLE OF A BAR MAGNET.

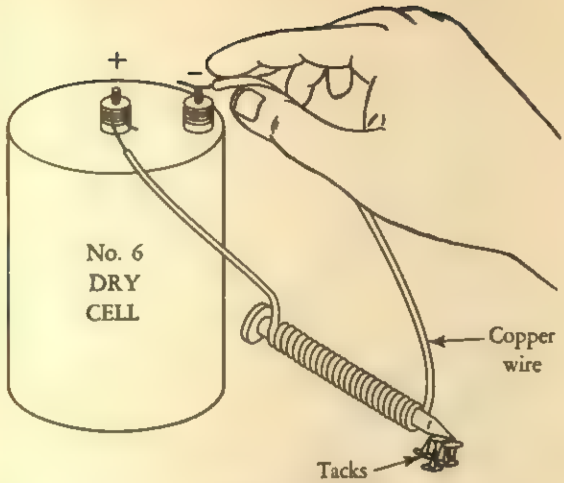


FIGURE 21–7.
AN ELECTROMAGNET IS A TEMPORARY MAGNET.

end to a terminal of a dry cell, and touch the other end to the second terminal for a few seconds (Figure 21–7). The nail will now pick up tacks and other objects made of iron or steel, and is called an electromagnet. When you remove the wire from one of the terminals, the electric current stops flowing and the nail loses its magnetism. (*Note:* Keep the wires connected to the dry cell for as short a time as possible. Otherwise the dry cell will be used up very quickly.)

12. *Make a permanent magnet by stroking* · Repeat Learning Activity 10 above, using a steel knitting needle instead of an iron nail. Note that the needle retains most of its magnetism after it has been set aside for 3 to 4 days.

Determine the poles of this magnetized needle by bringing a compass near it (see Learning Activity 7 above). Then cut the needle in half with cutting pliers. Each half will become a new magnet, with poles.

13. *Make a permanent magnet with electricity* · Obtain a cardboard tube, such as a mailing tube, about 10 inches long and 1 inch in diameter. Obtain some insulated thin copper wire (No. 26 or 28) from the hardware store. Wind the wire around the tube, covering almost all of the tube, leaving about 2 feet of wire free at each end. Connect two dry cells in series, as shown in Figure 21–8. Place a steel knitting needle all the way into the cardboard tube. Now touch the two end wires to the terminals of the dry cells, as shown in the diagram, for 2 to 3 seconds only. Remove the needle and test it for magnetism by picking up tacks and other iron or steel objects. The needle is now a strong, permanent magnet.

14. *Show how magnets can lose their magnetism* · Magnetize two large steel sewing needles by stroking them with one pole of a strong bar magnet, as described in Learning Activities 10 and 12 above. See how many iron filings or small tacks each needle will attract. Now hold one needle with forceps or pliers in the flame of a Bunsen burner or alcohol lamp for about 3 minutes. At the same time have one of the children pound the other needle repeatedly with a hammer. Now test both needles again to see how many iron filings each needle will attract. Point out that heating and striking or jarring a magnet will disarrange the molecules, causing the magnet to lose its magnetism.

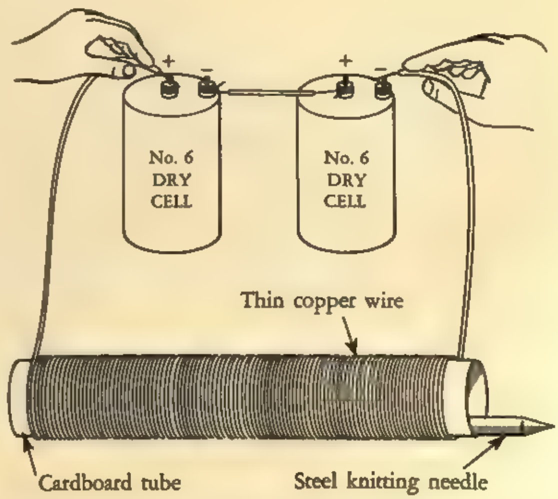


FIGURE 21–8.
MAKING A STEEL KNITTING NEEDLE BECOME A PERMANENT MAGNET.

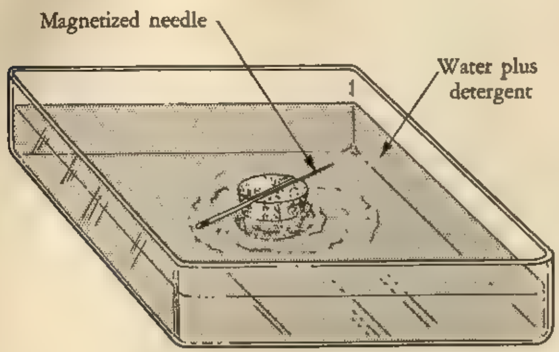


FIGURE 21–9.
A FLOATING, MAGNETIZED NEEDLE COMPASS.

15. *A freely moving magnet points north and south* · Set up a bar magnet so that it can swing freely, as described in Learning Activity 4 above. Keep the magnet away from any objects made of iron or steel. The magnet will eventually come to rest with its north-seeking pole pointing to the north. Point out that this behavior is exactly like that of a compass needle.

16. *Make a floating compass* · Magnetize a steel sewing needle by stroking it with one pole of a strong bar magnet, as described in Learning Activities 10 and 12 above. Slice a round, flat piece, about ⅛ inch thick, from a cork stopper. Cut a groove across the center of the top of the cork. Put the needle into the groove and place the cork into a glass, china, or aluminum dish filled with water (Figure 21–9). A teaspoon of detergent in the water will lower the surface tension of the water and prevent the cork from moving to one side of the dish and staying there. The needle will soon behave like a compass needle by assuming a north-south position because of the earth's magnetic field.

ELECTROMAGNETS

Note: Electromagnets draw a lot of current and can use up dry cells very quickly. When working with electromagnets, keep the wires connected to the dry cells for as short a time as possible.

1. *A wire carrying an electric current is magnetic* · Obtain some insulated copper bell wire (No. 18) from the hardware store. Remove the insulation from both ends of the wire and connect one end to a terminal of a dry cell. Now touch the other bare end of the wire to the second terminal of the dry cell for a few seconds and try to pick up some iron filings or finely cut-up steel wool with the middle part of the wire (Figure 21–10). The wire will attract the filings, showing that a wire carrying an electric current has a magnetic field around. Place a compass beside the wire, and then touch the bare end of the wire to the terminal of the dry cell again. The compass needle will move, showing that the magnetic field around the wire affects the magnetized needle.

2. *A coil of wire carrying an electric current acts like a magnet* · Wrap some insulated bell wire (No. 18) about 15 to 20 times around a pencil to form a coil, and then remove the pencil. Remove the insulation from both ends

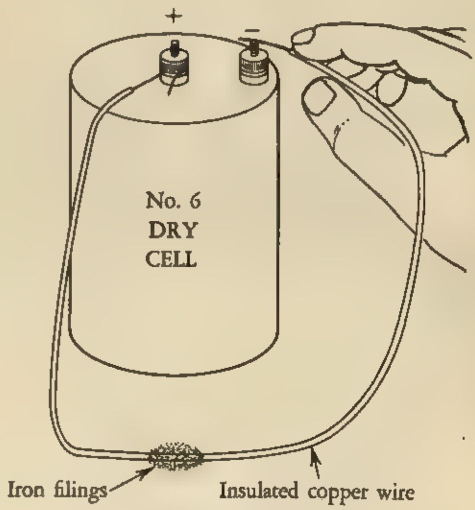


FIGURE 21–10.
WIRE CARRYING ELECTRIC CURRENT ACTS LIKE A MAGNET.

of the wire, connect one end to a terminal of a dry cell, and touch the other end to the second terminal for a few seconds (Figure 21–11). The coil will act like a magnet, picking up tacks and other objects made of iron or steel.

Determine the poles of this coil magnet by bringing a compass near it. The blue or black end of the magnetized compass needle is a north-seeking pole, so it will be attracted to the coil magnet's south-seeking pole and repelled by the north-seeking pole. Repeat Learning Activity 5 of "magnetism" (p. 738) to show the magnetic field around the coil of wire.

3. *Make a simple electromagnet* · Repeat Learning Activity 11 of "Magnetism" (p. 740). Note that the coil of wire and nail together make a stronger magnet than just the coil of wire alone, which is described in Learning Activity 2 above. Determine the poles of the electromagnet by bringing a compass near it, also as described in Learning Activity 2 above. Now reverse the connections of the wires to the terminals of the dry cells. Note that this reverses the direction of the current flowing through the wire, which causes the poles of the electromagnet to reverse as well.

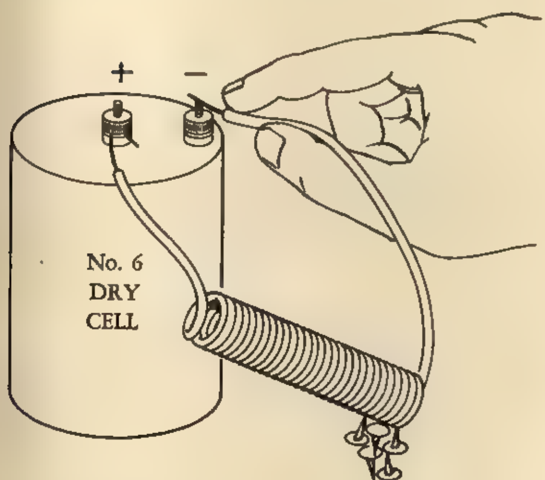


FIGURE 21–11.
A WIRE COIL CARRYING ELECTRIC CURRENT ACTS LIKE A MAGNET.

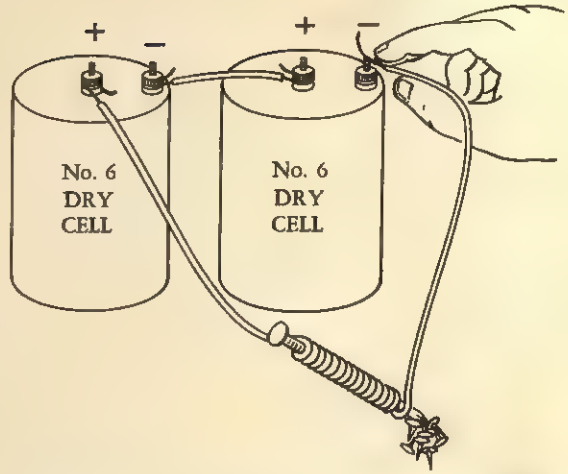


FIGURE 21–12.
INCREASING THE STRENGTH OF THE ELECTRIC CURRENT MAKES THE ELECTROMAGNET STRONGER.

4. *Making an electromagnet stronger* · Make an electromagnet as described in Learning Activity 3 above, winding the wire around the nail exactly 20 times. Count the number of tacks the electromagnet will attract. Now wind 20 more turns of wire around the same nail and again count the number of tacks the electromagnet will pick up. Doubling the number of turns will double the strength of the electromagnet.

Make another electromagnet with just 20 turns of wire and count the number of tacks it will pick up. Now connect the electromagnet to two dry cells aranged in series (Figure 21–12) and again count the number of tacks that will be attracted. Doubling the strength of the electric current will double the strength of the electromagnet. Have the children predict (and test) what will happen when both the number of turns and the strength of the electric current are doubled.

5. *Compare the electromagnet and the regular magnet* · Discuss the ways in which electromagnets are similar to and different from regular magnets. Compare their similarities with respect to polarity, magnetic field, and kinds of materials they will attract. Compare their differences

with respect to composition and permanence of magnetism, polarity, and strength.

6. *Make a simple telegraph set* · Obtain a wood board about 12 inches long, 9 inches wide, and ½ inch thick. Nail a block of wood about 3 inches high to one end of the board. Use tin snips to cut a strip of iron about 5 inches long and 1 inch wide from a metal can. Nail the metal strip to the top of the wood block, and then bend it down to form a dip (Figure 21–13). Drive a long nail with a large head (roofing nail) into the board so that its head is just below the metal strip. This part of the telegraph set is called the sounder.

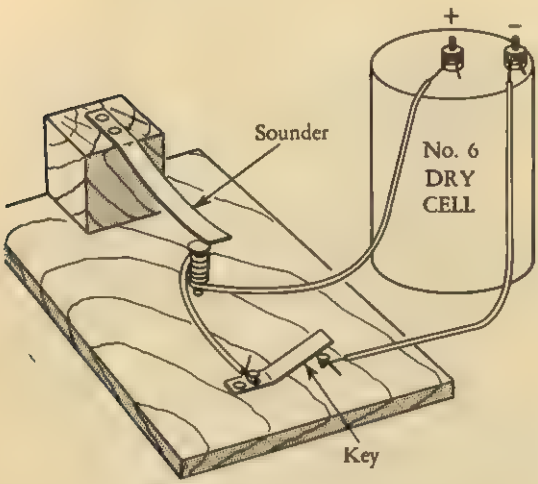


FIGURE 21–13.
A SIMPLE TELEGRAPH SET.

Now make a telegraph key. Nail one end of a second metal strip to the board, using two nails but driving one only partially into the board. Bend the strip back so that it angles away from the board. Drive a smaller roofing nail partially into the board so that its head is under the metal strip. Now wire the key and sounder, as shown in the diagram, using about 50 turns of wire around the nail. When you press the key, the sounder will click. (You may have to adjust the distance between the bent metal strip and the nail head of the sounder. Also, if the click is faint, you may have to use two dry cells connected in series, as shown in Figure 21–12.)

Detailed instructions for making a variety of single and two-way telegraph sets may be found in the reference and source books listed at the end of this chapter and in Chapter 7, "Materials for Teaching Science."

7. *Uses of electromagnets* · Have the children read about and report on the uses of electromagnets in communication, industry, and the home.

STATIC ELECTRICITY

Note: Learning Activities in static electricity should be conducted in the winter when the days are dry and cold.

1. *Static electricity can be produced by friction* · Rub a comb or plastic fountain pen briskly with a piece of wool cloth. The comb and pen will pick up small pieces of paper. Rub a blown-up balloon briskly with a piece of wool cloth and place it against the wall. The balloon will stick to the wool. Point out that in each case electrons were rubbed off the wool onto the objects, making both the objects negatively charged and the wool positively charged.

2. *The nature of static electricity* · Repeat Learning Activity 9 of "The Structure of Matter," Chapter 16 (p. 626) dealing with the structure of the atom. Show how electrons can be added or removed to make an atom negatively or positively charged.

3. *The law of electrostatic attraction and repulsion* · Blow up two balloons to the same size and suspend each balloon from a string so that they are 1 to 2 inches apart. Rub each balloon briskly with a wool cloth. The balloons will become negatively charged and repel each other (Figure 21–14). Now rub a glass test

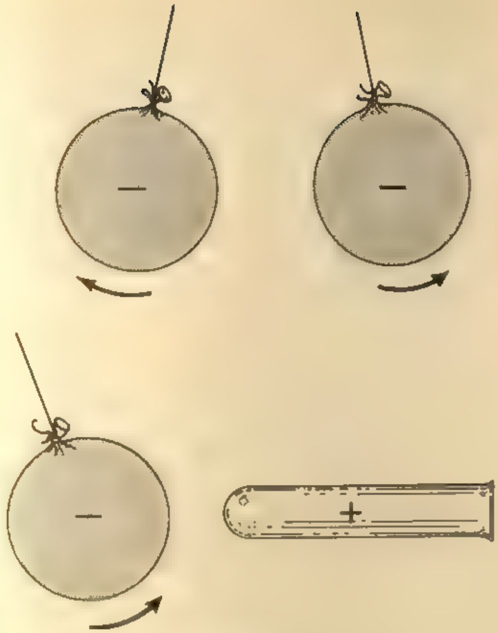


FIGURE 21–14.
LIKE CHARGES REPEL EACH OTHER; UNLIKE CHARGES ATTRACT EACH OTHER.

tube briskly with a piece of nylon or silk cloth and bring the test tube near each of the balloons. The test tube, having become positively charged, will attract the negatively charged balloons.

4. *Demonstrate some effects of static electricity* · Charge a comb by rubbing it briskly with a wool cloth. Allow a thin stream of water to flow from the faucet, and then hold the comb near the water. The stream will be attracted by the comb and bend towards it.

Charge a balloon by rubbing it briskly with wool cloth. Pass the balloon over a child's head and cause the hair to stand on end.

Rub a fluorescent light tube briskly with a piece of nylon or silk in a completely darkened room or closet. The fluorescent tube will glow faintly.

5. *The effect of charged materials upon uncharged materials* · Obtain a styrofoam ball and cut out a small piece about ¼ inch thick. (A pith ball of the same size can be obtained from a scientific supply house.) Suspend the styrofoam from a silk or nylon thread. Charge a comb negatively by rubbing it briskly with a wool cloth, and then bring the comb near the styrofoam (Figure 21–15). The styrofoam will be attracted to the comb because the negatively charged comb repels electrons from the side of the styrofoam nearest the comb, leaving this side positively charged. Now touch the styrofoam with the negatively charged comb. Electrons will flow into the styrofoam, making the styrofoam negatively charged, and the styrofoam will be repelled by the comb.

Charge a glass test tube positively by rubbing it briskly with silk or nylon. Make the

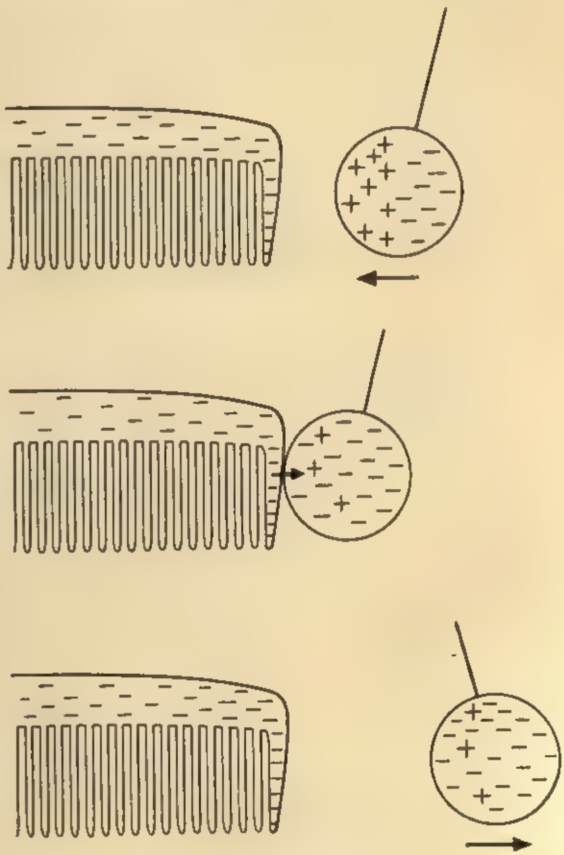


FIGURE 21–15.
A CHARGED BODY FIRST ATTRACTS, THEN REPELS, AN UNCHARGED BODY.

styrofoam neutral again by touching it with your fingers. Bring the positively charged test tube near the neutral styrofoam. The styrofoam will be attracted to the test tube because the positively charged test tube attracts electrons to the side of the styrofoam nearest the test tube, making this side negatively charged. Now touch the styrofoam with the positively charged test tube. Electrons will flow from the styrofoam into the test tube, leaving the styrofoam positively charged, and the styrofoam will be repelled by the test tube.

6. *Make an electroscope (electrical-charge detector)* • Obtain a bottle with a narrow neck and a cork stopper to fit. Obtain some insulated copper bell wire (No. 18) from the hardware store. Use an ice pick to make a small hole through the stopper. Force a piece of the bell wire, with all its insulation removed, through the stopper. Make an angular bend at the lower end of the wire and wind the upper end into a close circular coil (Figure 21–16). Hang a strip of thin aluminum foil about 3 inches long and ¼ inch thick, folded in half, over the angular bend of wire. The thin aluminum foil can be obtained from a chewing gum wrapper by soaking the wrapper in rubbing alcohol and then working the foil loose. Press the cork firmly into the neck of the bottle.

Now charge a comb negatively by rubbing it briskly with a wool cloth. Touch the comb to the wire coil on top, rubbing it back and forth a few times. Electrons will leave the comb and flow down the wire into the aluminum halves, charging them negatively and causing them to spread apart because they repel each other. Remove the comb.

The electroscope is now charged and can be used to direct and determine the unknown charges on other objects. Bring a charged object near (but not touching) the wire coil at the top. If the charged object is negative, more electrons will be repelled from the coil down into the aluminum halves. The aluminum halves will become more negatively charged and will spread farther apart. On the other hand, if the charged object is positive, some electrons from the aluminum halves will be attracted up to the coil on top. The aluminum halves will now become less negatively charged and will come closer together.

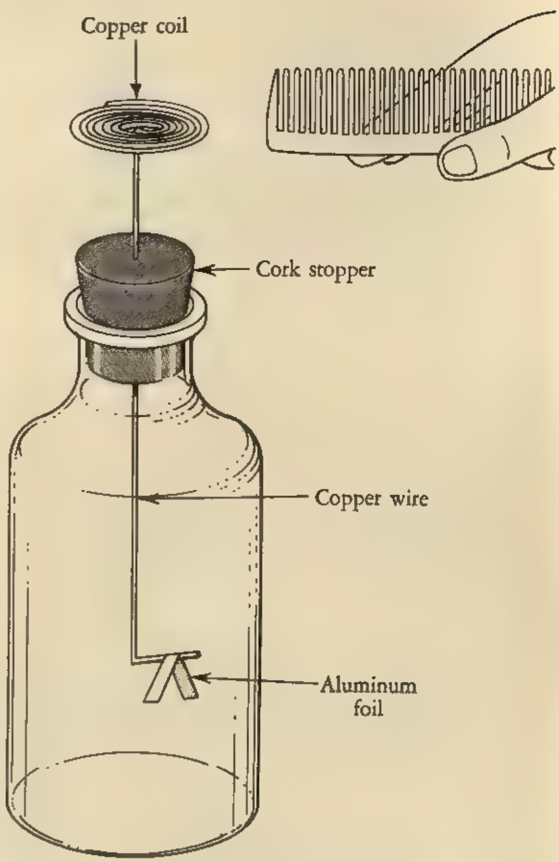


FIGURE 21–16.
AN ELECTRICAL CHARGE DETECTOR (ELECTROSCOPE).

To discharge the electroscope, touch the wire coil at the top with your fingers. Touching the coil allows electrons to leave the aluminum halves and travel through the wire, into your body, and then to the ground. The aluminum halves become neutral and collapse together.

7. *Only nonconductors build up electrostatic charges* • Charge a blown-up balloon by rubbing it briskly with a wool cloth and determine its charge with an electroscope, as described in Learning Activity 6 above. Repeat, using a

glass test tube that has been rubbed briskly with silk or nylon.

Now rub metal objects, such as nails and coins, and bring them near the electroscope. No static charge will be detected. Point out that good conductors, like metals, do not build up an electrostatic charge because, as soon as they acquire electrons, they conduct electrons to the ground.

8. *Produce electric sparks by static electricity* · Have the children shuffle across the rug in a darkened room, and then touch a metal object. In addition to the shock, an electric spark is produced. The same effect is created when a blown-up balloon is charged by rubbing briskly with a wool cloth and then is touched to the metal object. Point out that static electricity has now been converted to current electricity.

9. *Lightning and thunder* · Have the children read about and report on how lightning and thunder are produced. Compare lightning and thunder with the electric spark and crackle produced in Learning Activity 8 above. Draw diagrams to show how lightning is produced within a cloud, from cloud to cloud, from cloud to ground, and from ground to cloud.

10. *Common occurrences of static electricity* · Have the children describe and make a list of common static electricity phenomena they have seen or that can occur at home or school and in an automobile.

CURRENT ELECTRICITY

1. *The nature of current electricity* · Repeat Learning Activity 9 of "The Structure of Matter," Chapter 16 (p. 626) dealing with the structure of the atom. Show how the flow of electrons from atom to atom within a material constitutes an electric current.

2. *Make a simple electric circuit* · Obtain a No. 6 dry cell, insulated copper bell wire (No. 18), a one-cell flashlight bulb, and a small porcelain socket to hold the bulb from a scientific supply house or a hardware store. Set up a simple electric circuit, as shown in Figure 21–17, being sure to remove the insulation from the ends of the wires. Trace the flow of current through the completed circuit. Now

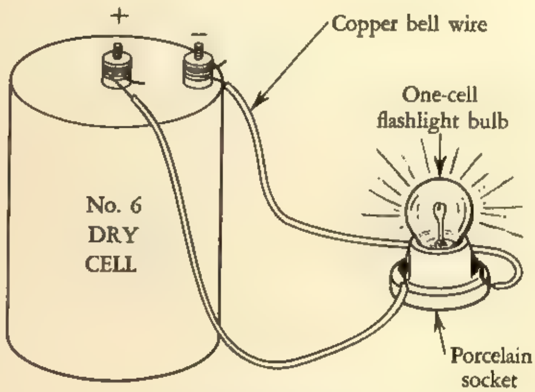


FIGURE 21–17.
A SIMPLE ELECTRIC CURRENT.

break the circuit by disconnecting one of the wires attached to the dry cell or porcelain socket.

3. *Conductors and nonconductors* · Connect a dry cell, insulated copper bell wire (No. 18), one-cell flashlight bulb, and porcelain socket as shown in Figure 21–18, being sure to remove the insulation from the ends of the wires. Touch the bare ends of the two wires to a nail, the metal part of a pen or pencil, various coins, aluminum foil, and pieces of wood, rubber, cloth, and glass. Note which kinds of materials do and do not conduct electricity. Establish the relationship between electrical conductivity and how tightly or loosely the atoms hold some of their electrons.

4. *The electric switch* · Obtain a knife switch from the hardware store or scientific supply house. Insert the switch into the simple electric circuit described in Learning Activity 2 above (Figure 21–19). Operate the switch and show

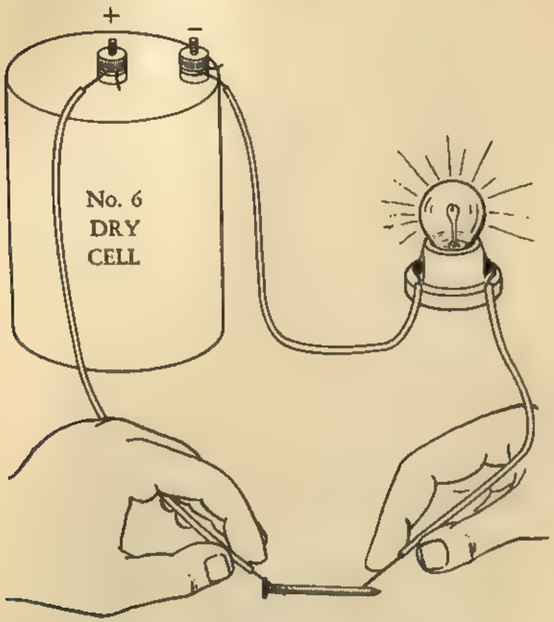


FIGURE 21–18.
A NAIL IS A GOOD CONDUCTOR OF ELECTRICITY.

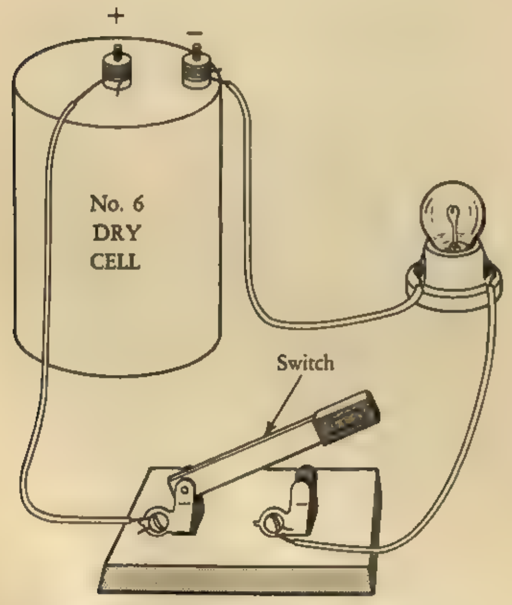


FIGURE 21–19.
A KNIFE SWITCH CAN OPEN AND CLOSE AN ELECTRIC CIRCUIT.

how it closes and opens the circuit. Replace the knife switch with a pushbutton switch and a snap switch.

Make your own switch by cutting a strip of iron, about 5 inches long and 1 inch wide, with tin snips from a metal can. Nail one end of the strip to a small wood board. Use two nails, but drive one only partially into the board. Bend the strip back so that it angles away from the board. Drive a small roofing nail partially into the board so that its head is under the metal strip. Now insert this homemade switch into your simple circuit, as shown in Figure 21–20.

FIGURE 21–20.
A HOMEMADE SWITCH.

Operate the switch to open and close the circuit.

5. *Connect appliances in series and in parallel* · Connect three porcelain sockets and one-cell flashlight bulbs in series, as shown in Figure 21–21. Note that the electric current flows through each bulb, one after the other, and the bulbs light up dimly. Unscrewing one

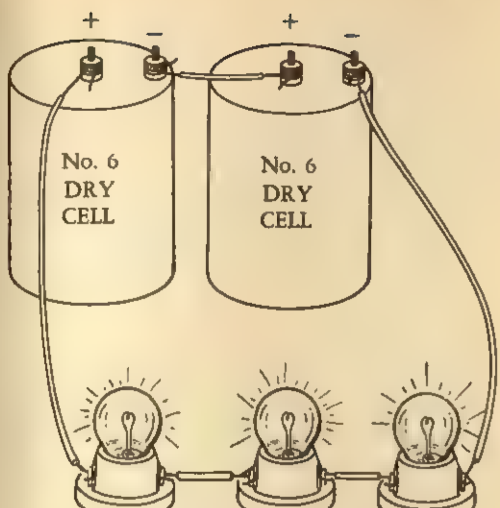


FIGURE 21–21.
FLASHLIGHT BULBS CONNECTED IN SERIES.

of the bulbs will break the complete circuit so that the other bulbs go out.

Now connect the sockets and bulbs in parallel as shown in Figure 21–22. Point out

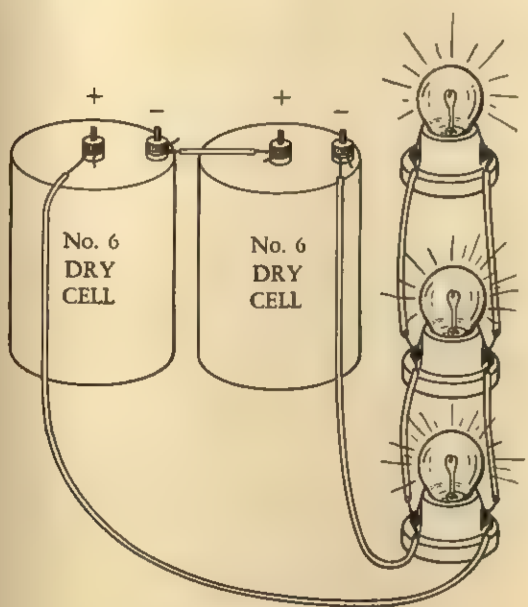


FIGURE 21–22.
FLASHLIGHT BULBS CONNECTED IN PARALLEL.

that the current branches off so that part of the current goes through one socket and part goes on to the next socket. Note how brightly lighted all the bulbs are. Unscrewing one of the bulbs will break only that part of the circuit that flows through the bulb so that the remaining two bulbs continue to stay lighted. If you unscrew a second bulb, the third bulb will still continue to burn.

6. *Produce a short circuit* · Make a simple circuit as described in Learning Activity 2 above. However, remove some insulation from the middle of each wire so that the bare wires are exposed. Place the blade of a screw driver across both bare wires, only for a second or two, and the bulb will go out (Figure 21–23).

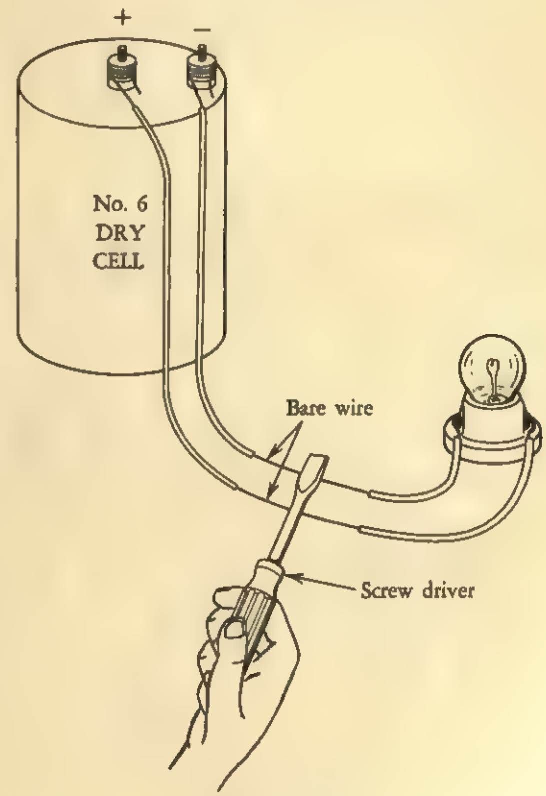


FIGURE 21–23.
THE BLADE OF THE SCREWDRIVER PRODUCES A SHORT CIRCUIT.

Trace the shorter path (or circuit) that the electric current now travels. Produce a short circuit again by pressing the bare wires together with your fingers, and feel how hot the wires become.

7. *Show how a fuse works* · Make a short circuit setup as described in Learning Activity 6 above. However, use two dry cells in series, place a two-cell flashlight bulb in the socket, and insert a homemade fuse (Figure 21–24). To make the homemade fuse, obtain two thumb tacks and two paper clips, and press them into one end of a small wood board so that the paper clips are upright and about 1 inch apart. Cut a narrow strip of aluminum foil and insert it between the paper clips. When you produce a short circuit by placing the blade of a screw driver across the bare wires, the aluminum foil will melt and break the circuit. (If the room is darkened, you may see the aluminum glow as it becomes hot and melts.)

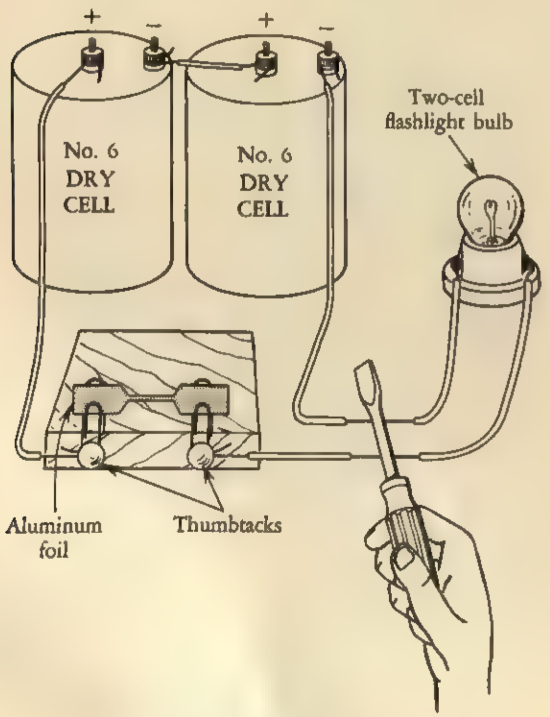


FIGURE 21–24.
A HOMEMADE FUSE.

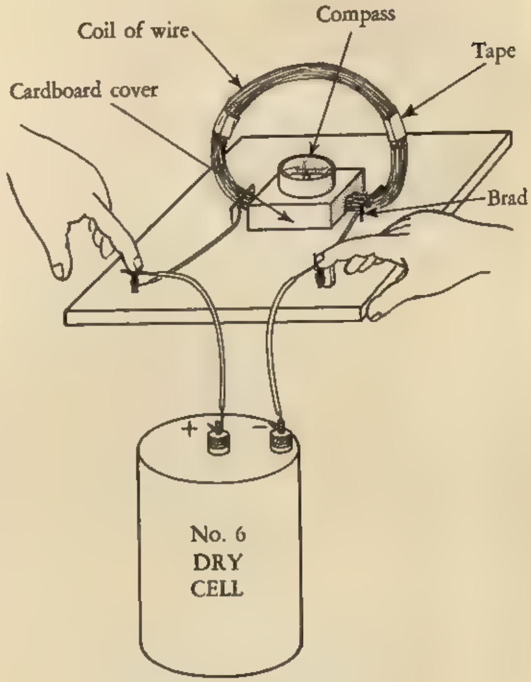


FIGURE 21–25.
A CURRENT DETECTOR (GALVANOMETER).

Have the children examine a screw-type house fuse and note the short strip of easily melted metal in the fuse. Compare the appearance of a fresh and a burned-out fuse.

8. *Make a galvanometer* (*current detector*) · Obtain some insulated thin copper wire (No. 26 or 28) from a scientific supply house or the hardware store. Wind about 100 turns of this wire around a cylindrical glass jar, about 3 inches in diameter, to form a narrow coil. Slip the coil off the jar and tape it at two or three points to hold the wires neatly in place. Leave a few inches of wire free at each end of the coil and remove about 1 inch of insulation from each end of the wire. Use two brads to attach the coil to a small wood board and to hold the coil upright (Figure 21–25). Place the cover of a small cardboard box inside the coil, first cutting grooves on each side of the cover so that it will rest in a stable and even position on the board. Drive two small nails almost all

the way into the board and wrap the bare end of each wire around a nail.

Now rest a compass on top of the cardboard cover, and turn the board until the compass needle is parallel with the direction of the coil. Then turn the compass until the N and S letters are under the needle. Your galvanometer is now ready to operate. Connect a dry cell to the galvanometer by touching the bare ends of the wires from the dry cell to the nails of the galvanometer. The compass needle will be deflected, showing the presence of an electric current. Point out that, when an electric current flows through the galvanometer coil, a magnetic field is formed that affects the magnetized compass needle. The greater the current flowing through the coil, the stronger the magnetic field will be, and the more the compass needle will be deflected.

9. *Electrical units of measure* · Have the children examine a variety of electrical appliances in the home (such as light bulbs, toasters, heaters, and motors) and list the number of watts printed on each appliance. Have the children calculate the current each appliance will draw, assuming that 120 volts is being used. Then let them find the resistance of each appliance.

Have the children observe an electric meter when electricity is passing through it. Study the units on each dial and develop an understanding of the watt, kilowatt, and kilowatt-hour.

10. *Make a simple electric cell* · Dissolve a tablespoon of common table salt in a glass tumbler of warm water. Obtain an iron washer, a penny, and two lengths of insulated copper bell wire (No. 18). Remove about 3 inches of insulation from one end of each wire and about 1 inch of insulation from the other end. Wrap the penny and the washer separately with the longer bare end of the wire and suspend them in the salt water by bending the wires tightly over the edge of the tumbler (Figure 21–26). Make sure that the coil and the washer are not touching each other. Now touch the other ends of the wires to the nails of the galvanometer

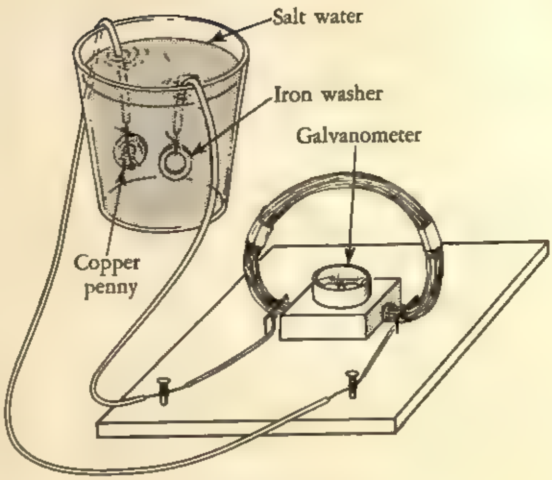


FIGURE 21–26.
A SIMPLE ELECTRIC WET CELL.

described in Learning Activity 8 above. The compass needle will be deflected, showing the presence of an electric current. Repeat the activity, using other combinations of two different metals. Point out that chemical energy has been changed into electrical energy.

11. *Examine a dry cell* · Cut a used-up dry cell lengthwise in half with a hack saw. Examine each part and discuss its function.

12. *Examine a storage battery* · Have the children examine 6-volt and 12-volt storage batteries in automobiles. Draw a diagram of the parts of a storage battery and discuss their function. Point out that storage batteries, unlike most dry cells, can be recharged.

13. *Generate electricity with a magnet and a coil of wire* · Wind about 50 turns of insulated copper bell wire (No. 18) around a cylindrical glass jar, about 2 to 3 inches in diameter, to form a coil. Slip the coil off the jar and tape it at a few points to hold the wires neatly in place. Leave about 3 feet of wire free at each end of the coil and remove the insulation from the end of each wire. Connect the coil to a galvanometer (described in Learning Activity 8 above) as shown in Figure

21–27. Hold the coil as far away from the galvanometer as possible and move the center of the coil across a bar magnet. The compass needle of the galvanometer will be deflected,

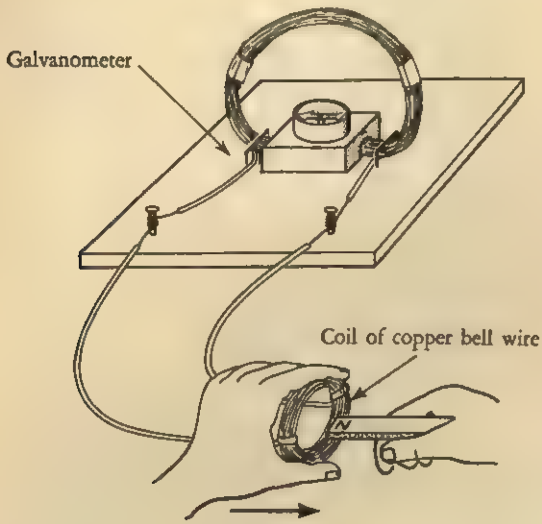


FIGURE 21–27.
GENERATING ELECTRICITY WITH A MAGNET AND COIL OF WIRE.

showing the presence of an electric current. When you move the coil in the opposite direction, the needle is also deflected in the opposite direction. When you hold the coil stationary, there is no deflection because no lines of force in the magnetic field are being cut. When you move the coil continuously back and forth across the magnet, a continuous alternating current is produced. Repeat the learning activity, this time holding the coil stationary and moving the magnet. Point out that mechanical energy is being changed into electrical energy.

14. *Make a model generator* · Detailed instructions for making a variety of simple generators may be found in the reference and source books listed at the end of this chapter and in Chapter 7, "Materials for Teaching Science."

15. *The photoelectric cell* · Bring in a camera with a built-in light meter and explain the operation of the photoelectric cell. Use a light meter to measure the illumination at different parts of the classroom. Point out that electrical energy is being obtained from light energy.

16. *Make a thermocouple* · Cut off a piece of wire from a coat hanger and scrape the paint away from both ends. Obtain two pieces of copper bell wire (No. 18) and remove the insulation from the ends of both wires. Tightly twist together one end of a copper wire to each end of the coat hanger wire and connect the other free ends of each copper wire to a galvanometer (described in Learning Activity 8 above). Now place one of the twisted ends into a glass tumbler containing cold water and ice cubes, and heat the other twisted end with the flame of an alcohol lamp or Bunsen burner (Figure 21–28). The compass needle of the galvanometer will be deflected, showing the presence of an electric current. Point out that heat energy has been changed into electrical energy.

17. *Make a model electric motor* · Detailed instructions for making a variety of simple

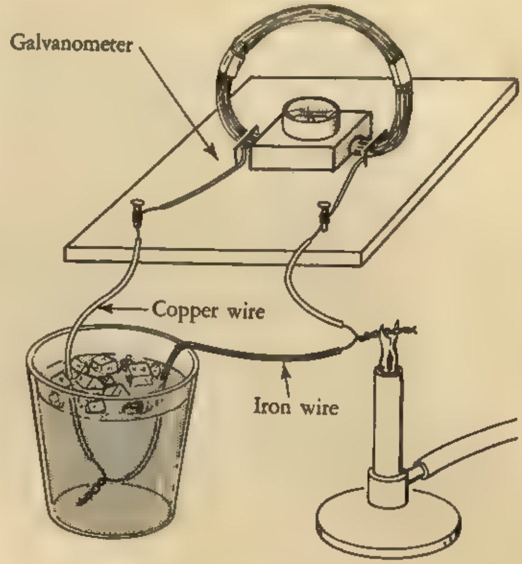


FIGURE 21–28.
GENERATING ELECTRICITY WITH A THERMOCOUPLE.

model motors may be found in the reference and source books listed at the end of this chapter and in Chapter 7.

18. *Electricity can plate materials* · Obtain some copper sulfate crystals, a small amount of dilute sulfuric acid, and a copper strip from your high school chemistry teacher. Put a heaping tablespoon of copper sulfate into a glass tumbler of warm water and stir vigorously until the copper sulfate dissolves. Then add a few drops of the sulfuric acid. Obtain two pieces of copper bell wire (No. 18), each piece about 24 inches long. Remove quite a bit of the insulation from the end of one piece of wire and wrap a few turns of bare wire around one end of the copper strip, making sure you have a good contact between the strip and the wire. Bend the copper strip so it will hang over a pencil placed across the rim of the tumbler (Figure 21–29).

Wrap the bare end of the second piece of wire around a house key and suspend the key in the copper sulfate solution by wrapping the wire around the pencil. Now connect the other bare ends of both wires to two dry cells connected in series, as shown in the diagram, making sure that the key is connected to a negative terminal and the copper strip is connected to a positive terminal. Allow the current to flow for 15 minutes, and then disconnect the wires and remove the key. The key will be coated with copper.

19. *Uses of electricity* · Have the children read about and report on how electricity is converted to motion, heat, light, and sound in the home, school, and in industry. Let them make a list of all the appliances they can think of that make use of electricity.

20. *Safety rules* · Have the children make either one composite list or several individual lists of safety rules for using and handling electric appliances, wires, switches, and fuses.

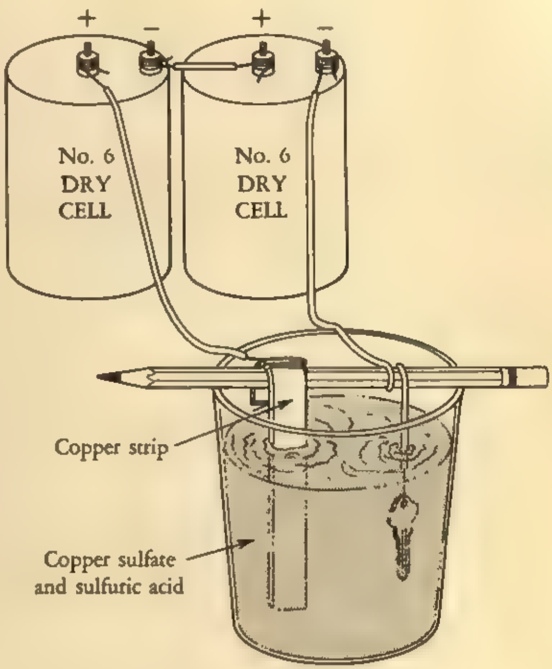


FIGURE 21–29.
COATING A KEY WITH COPPER.

BIBLIOGRAPHY FOR "MAGNETISM AND ELECTRICITY"

BENDICK, JEANNE. *Electronics for Young People.* New York: McGraw, 1955. 189 pp.

BENDICK, JEANNE, and ROBERT BENDICK. *Television Works Like This.* New York: McGraw, 1953. 63 pp.

BRANLEY, FRANKLYN M., and ELEANOR K. VAUGHAN. *Mickey's Magnet.* New York: Crowell, 1956. 48 pp.

COLLINS, A. FREDERICK. *The Radio Amateur's Handbook* (10th ed.). New York: Crowell, 1957. 352 pp.

EPSTEIN, SAM, and BERYL EPSTEIN. *The First Book of Electricity*. New York: Watts, 1953. Unpaged.

FERAVOLO, ROCCO V. *Junior Science Book of Electricity*. Scarsdale, N.Y.: Garrard, 1960. 61 pp.

FREEMAN, IRA M. *All About Electricity*. New York: Random, 1957. 141 pp.

FREEMAN, MAE, and IRA FREEMAN. *The Story of Electricity*. New York: Random, 1961. 79 pp.

GOULD, JACK. *All About Radio and Television*. New York: Random, 1953. 143 pp.

LEWELLEN, JOHN. *Understanding Electronics*. New York: Crowell, 1957. 213 pp.

MARCUS, ABRAHAM, and REBECCA B. MARCUS. *Power Unlimited!* Englewood Cliffs, N.J.: Prentice-Hall, 1959. 152 pp.

MEYER, JEROME S. *Picture Book of Radio and Television*. New York: Lothrop, 1951. 40 pp.

MORGAN, ALFRED. *The Boy Electrician*. New York: Lothrop, 1957. 407 pp.

———. *The Boys' Book of Engines, Motors, and Turbines*. New York: Scribner, 1954. 264 pp.

———. *The Boys' First Book of Radio and Electronics*. New York: Scribner, 1954. 229 pp.

———. *The Boys' Third Book of Radio and Electronics*. New York: Scribner, 1962. 277 pp.

———. *A First Electrical Book for Boys*. New York: Scribner, 1954. 263 pp.

PAGE, ROBERT MORRIS. *The Origin of Radar*. New York: Doubleday, 1962. 196 pp.

PARKER, BERTHA M. *Electricity*. New York: Harper, 1959. 36 pp.

———. *Magnets*. New York: Harper, 1958. 36 pp.

PINE, TILLIE S., and JOSEPH LEVINE. *Electricity and How We Use It*. New York: 1962. 48 pp.

PODENDORF, ILLA. *The True Book of Magnets and Electricity*. Chicago: Childrens, 1961. 47 pp.

POSIN, DANIEL Q. *What Is Electronic Communication?* Chicago: Benefic, 1961. 48 pp.

REUBEN, GABRIEL H., and GLORIA ARCHER. *What Is a Magnet?* Chicago: Benefic, 1959. 48 pp.

SCHNEIDER, HERMAN, and NINA SCHNEIDER. *More Power to You*. Chicago: Scott, 1953. 128 pp.

STODDARD, EDWARD. *The First Book of Television*. New York: Watts, 1955. 63 pp.

SYROCKI, B. JOHN. *What Is Electricity?* Chicago: Benefic, 1960. 48 pp.

VICTOR, EDWARD. *Magnets*. Chicago: Follett, 1962. 32 pp.

YATES, RAYMOND F. *A Boy and a Motor*. New York: Harper, 1944. 11 pp.

ZIM, HERBERT S. *Lightning and Thunder*. New York: Morrow, 1952. Unpaged.

INDEX

M